SPECIAL: 1989 SKY PREVIEW

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Missions to Venus and Jupiter

Astronomy in the Year 2000

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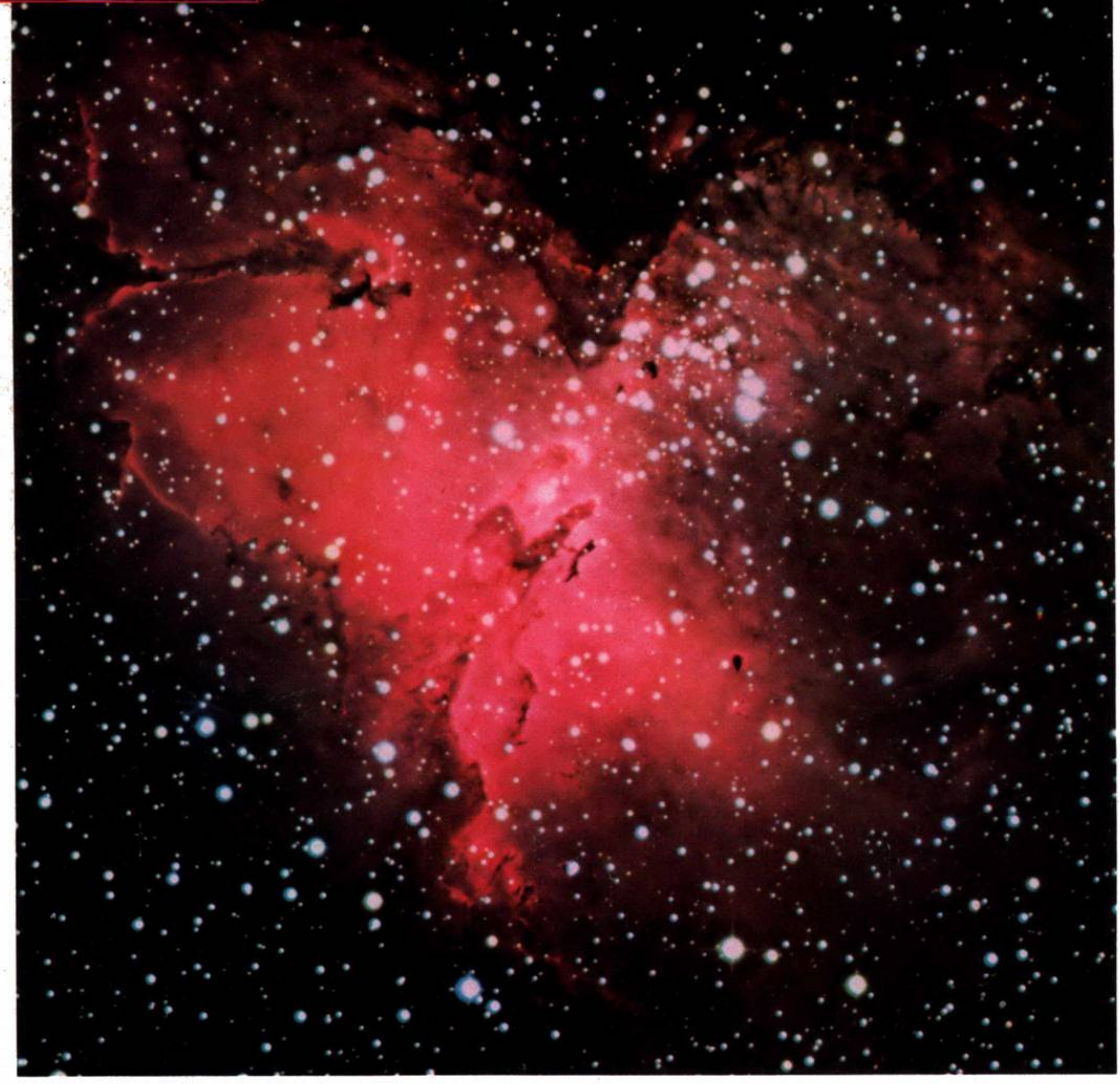

The Eagle Nebula

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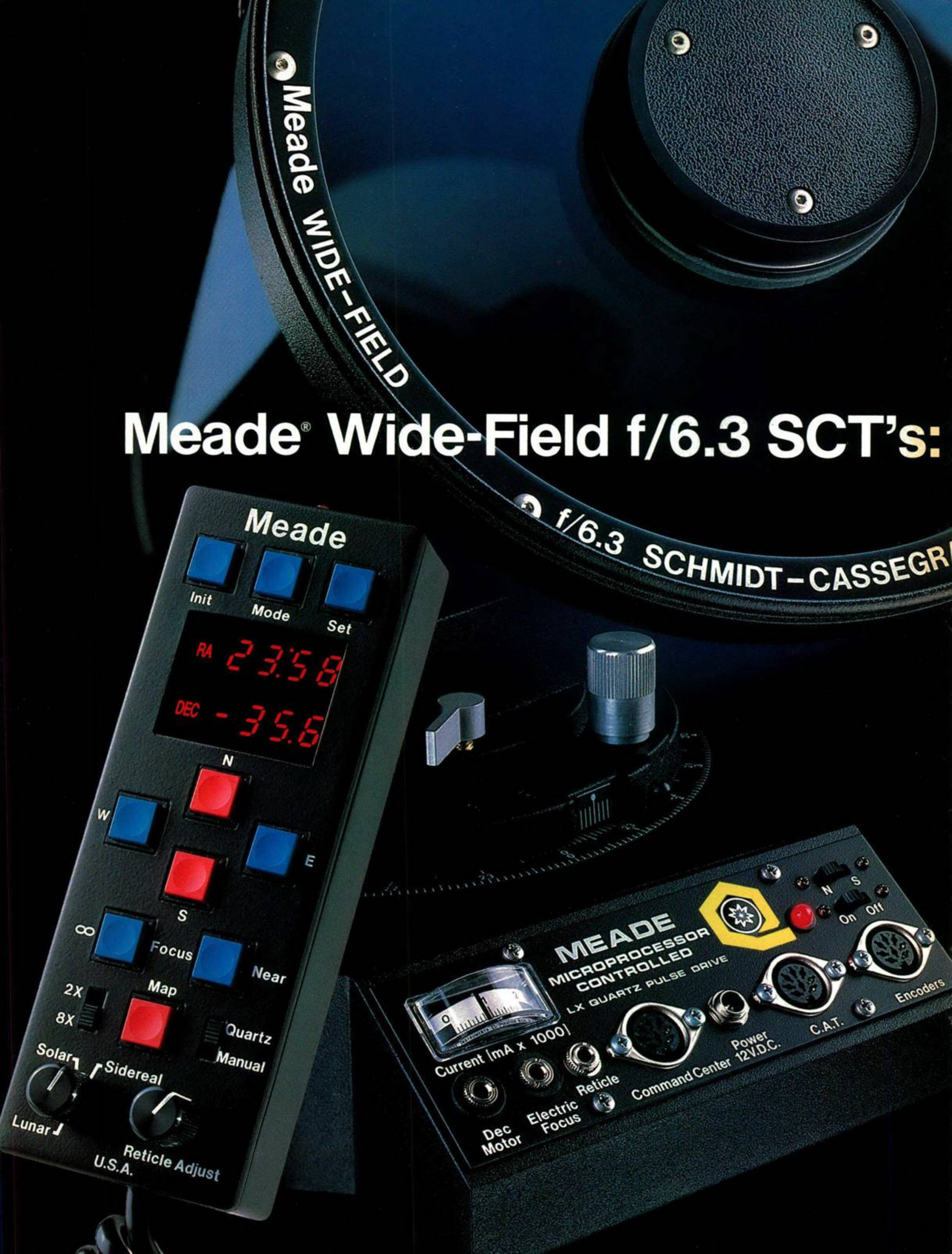
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Electric Focus
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The LX6 Revolution Is Here.

For the First Time Ever — Wide-Field Schmidt-Cassegrain Telescopes that Yield a 60% Reduction in Photo Exposure Times!

New Meade 8" and 10" LX6 Wide-Field Schmidt-Cassegrains combine the wide fields of view, fast photo exposure times, and high-contrast imaging long sought by the serious amateur. Consider this listing of *standard* LX6 features:

1 Fast f/6.3 Schmidt-Cassegrain Optics — *Optics that yield photographic and visual performance impossible to achieve with the f/10 optics that are standard on all other SC telescopes. Eyepiece for eyepiece, obtain:*

☐ A field of view that is **59%** wider than with f/10 Schmidt-Cassegrains. Use the Meade Super Wide Angle 40mm eyepiece on the 8" LX6 to obtain a true field over *2 degrees* in diameter!

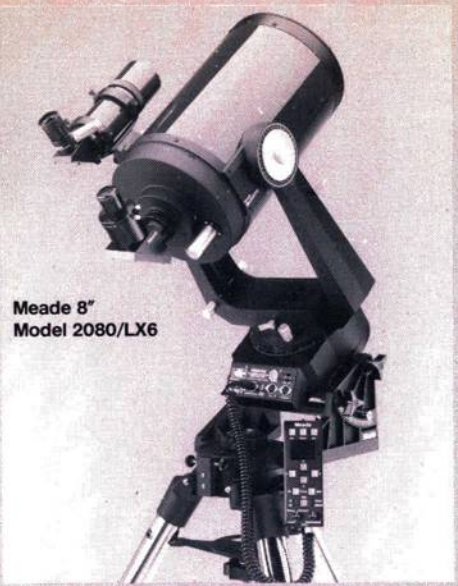
☐ Images both visually and photographically that are **2½ times** brighter than with an f/10 system.

☐ A **60%** reduction in astrophoto exposure times: 30 minute exposures become 12 minute exposures. Used with modern fast films, a **5-minute** color exposure of the Orion Nebula (M42) taken with the 10" Model 2120/LX6 *yields virtually all of the nebular detail that is theoretically possible to obtain with a 10" telescope!* With the optional Meade **Telecompressor Lens**, for an effective focal ratio of f/3.15, this exposure time is reduced still further to about **3 minutes** — an unheard of exposure time for a photovisual telescope of 10" aperture, an exposure time that means *anyone* with an absolute minimum of experience can take magnificent deep-space astrophotos!

2 Ultra High Contrast Baffling — In addition to their superlative wide-field deep-space performance, Meade 8" and 10" LX6 models, because of their computer-optimized internal light baffles, yield uncompromised, high-contrast lunar and planetary images. Add the Meade 3-element **#140 2X Telenegative Barlow Lens** to obtain high-power lunar and planetary images at f/12.6.

3 Built-In Digital Readout Capability — One of the most important optional features ever made available on a Schmidt-Cassegrain: now you can find faint objects in seconds, not minutes. The LX6 Digital Readouts, located on the hand controller display, permit continuous monitoring of: *(a) telescope position in RA and Dec; (b) Local Time; (c) Sidereal Time; (d) a Digital Timer for photo exposures; and (e) Frequency readout of the pulse motor's input current* — a feature that enables extremely precise digital settings of the telescope's drive rate, readable to within ±.01 Hz. The observer simply depresses the "Mode" button on the hand controller to read out the listed data sequentially.

The Digital Readout package can be internally added easily and rapidly to the hand controller of your LX6, either at the time of purchase or at any future date, and is available at only modest additional cost.



Meade 8"
Model 2080/LX6

4 New Multi-Function Electronic Command Center — The ECC hand controller, included as standard equipment, puts virtually every telescope function at your fingertips:

☐ *2X Drive Correction Speed* for precise electronic corrections during astrophotography.

☐ *8X Scanning Speed* for rapid electronic centering of the image in the field, or for roving about a specific sky region at 8 times the sidereal speed. Add the optional Declination motor for full dual-axis capability at 2X or 8X speeds.

☐ *Optional Digital Readouts*, described above.

☐ *Plus 6 other functions* that make Meade LX6's the only state-of-the-art Schmidt-Cassegrains available.

5 Quartz Microprocessor-Controlled Electronic and Drive Systems — The heart of every LX6 electronic system is a dedicated microprocessor that continuously controls, with quartz precision, all important electronic operations of the telescope, from the drive-rate frequency input to the main RA pulse motor, to the Electronic Command Center's multi-function digital readouts.

Augmented by the microprocessor, the RA pulse motor and LX worm gear system achieve true sidereal-rate tracking within ±.005% of the sidereal frequency, and with greater reliability than ever before. Switch to the "Manual" mode for variable Solar, Lunar, or Planetary tracking rates.

6 Advanced-Design Power Panel — Virtually every modern electronic accessory you might wish to add to your LX6 can be plugged-in directly to the telescope's power panel — accessories including the Meade **CAT Computer Aided Telescope** system *(see our other ad in this issue)*, with its library of more than 8000 astronomical objects; **Digital Readouts**, readable on the LX6 hand controller *(see above)*; **#1200A Electric Focuser**, for ultraprecise microfocusing; **12mm Illuminated Reticle Eyepiece**, for guiding during astrophotography; and the **Declination Motor**, for 2X/8X dual-axis operation.

In addition, the LX6 power panel includes an **Ammeter**, which continuously displays electric current usage, to gauge battery life during power cell operation; a **North-South Switch**, permitting your LX6 to be used anywhere in the world — simply flip the N-S switch to reverse drive direction for use in the Southern hemisphere; and **12-volts DC Power Inlet**. Each LX6 includes power cords for *3 types* of field operation: Directly from auto cigarette lighter plugs; directly from 115v. AC home outlets; and from the Battery Pack, included, using AA-size batteries supplied by the user.

7 Plus all of the features you expect on a top-of-the-line Meade Schmidt-Cassegrain — *Standard* features that include a **Super Plössl 26mm eyepiece** for exquisite definition and resolution across the entire visual field; 1/10-wave flat, multi-coated **2" Diagonal Mirror** with eyepiece holders for both 1¼" and 2" eyepieces; **9 x 60mm Polar Illuminated Viewfinder**, the largest finder available on a commercial SCT; **Multi-Coated Optics Group**, with multi coatings on all lens and mirror surfaces for maximum light transmission and image brightness; **Equatorial Wedge**, with magnetic compass, latitude scale, bubble level, and micrometric azimuth control; and **Variable-Height Field Tripod**, the most stable in the industry.

Priced only slightly higher than conventional f/10 Schmidt-Cassegrains, Meade 8" and 10" LX6 models achieve photographic and visual performance levels unobtainable with any competing telescopes.

Call or visit your Meade dealer now for further details and prompt delivery of the Meade 8" Model 2080/LX6 or 10" Model 2120/LX6 — from the World's leading manufacturer of Schmidt-Cassegrain telescopes.

Bulletin LX6 — Available at no charge, includes complete technical specifications, descriptions, and applications, with astrophotos, of Meade LX6 models.

Complete Catalog Package #88C — $3.00 — Includes catalogs and bulletins on the entire range of Meade astronomical telescopes, Series 4000 eyepieces, and accessories.

Dealer Locations and Assistance — For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments toll-free from anywhere in the continental U.S.A. (except California): **1-800-854-7485**. From all other areas, including California, call direct (714) 556-2291.

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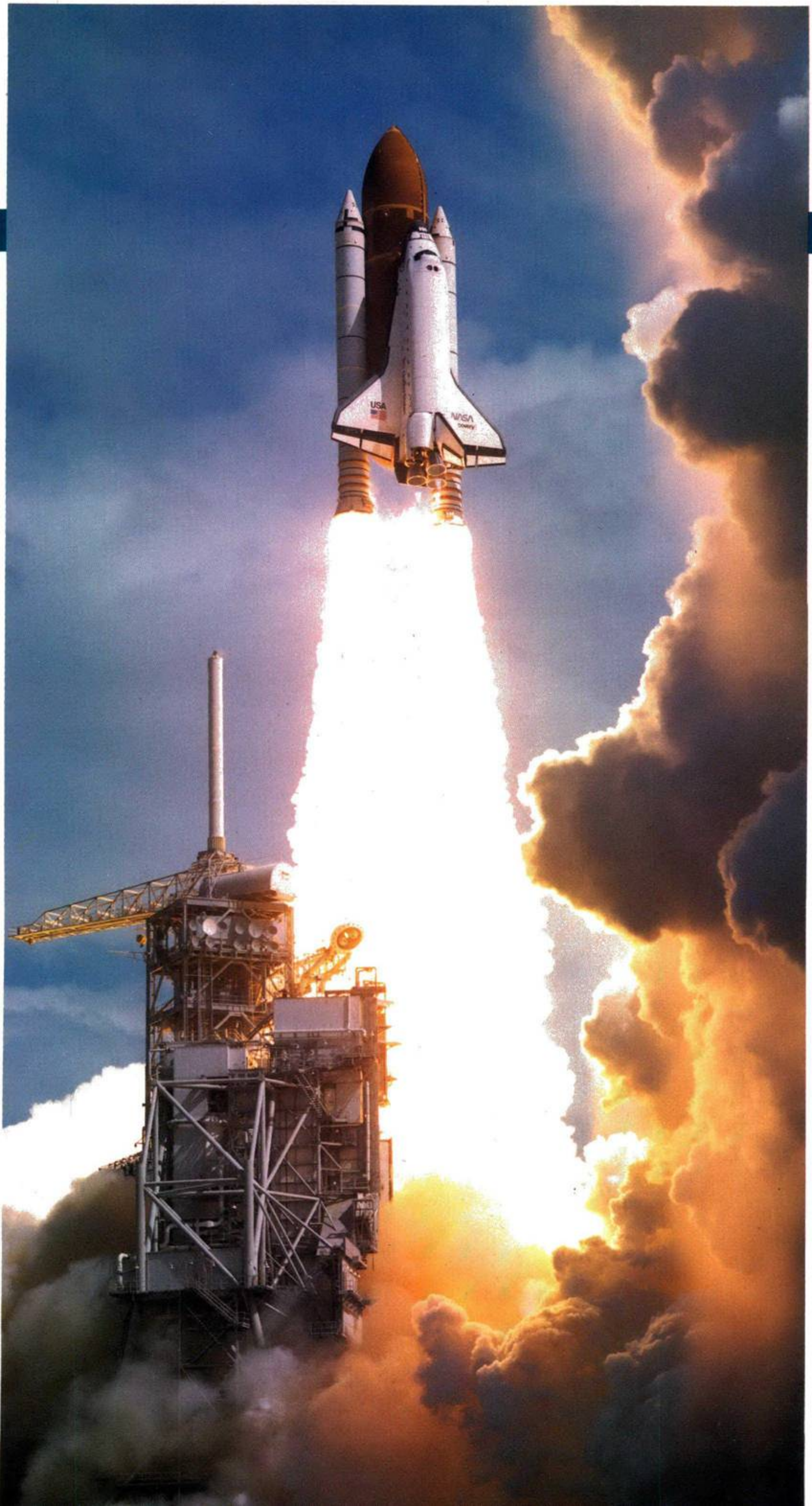
ON THE COVER: A cluster of stars nestles inside the glowing gas cloud known as the Eagle Nebula. Alister Ling takes you on a tour of winter's bright clusters beginning on page 98.



NASA FLIES AGAIN as the space shuttle *Discovery* clears the tower September 29, 1988, and heads for Earth orbit. The mission marked the first shuttle flight in thirty-two months.

ASTRONOMY®

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Behind the Scenes

NEW BEGINNINGS

As *Discovery* spit flame and tore into the sky, my heart climbed into my throat. Although the accident happened nearly three years ago, the memory of *Challenger's* destruction — a ball of fire and falling debris — was still vivid. *Discovery* roared toward the moment of Q-max, soared effortlessly through "throttle up," and then sailed serenely into orbit. I relaxed. At long last, I thought, we're back.

With this new beginning, America reclaims her place in space. This issue of ASTRONOMY focuses on astronomy from space and what current and future research will bring to astronomy. In preparing this month's features, we concentrated on two specific time frames: the present and the next two decades of space astronomy.

The immediate future holds missions to Venus and Jupiter, to be launched from the shuttle's cargo bay this April and October. *Magellan* will fly to Venus to map the surface of Earth's "sister" planet, while *Galileo* will begin a six-year journey to the giant planet Jupiter. Steve Cole profiles these missions in our first feature, which begins on page 22.

In the next few years NASA will launch a variety of little-known missions designed to answer specific scientific questions. Although they lack the "pizzazz" of the big multipurpose missions, their impact on astronomy will be enormous. What role do these special-purpose missions play in our space program? Steve Maran's feature story answers these questions.

And the long-term outlook? To answer that question, we selected key sections from a major report issued by the National Academy of Sciences, that propose goals in space science for America from 1995 through the year 2015. You'll read what America's top astronomers, planetary scientists, and astrophysicists hope to learn about the universe.

Finally — we couldn't resist — we have a short picture feature on the flight of *Discovery*. Join ASTRONOMY in celebrating a space program that's flying again!

We also hope you'll enjoy a different sort of new beginning: ASTRONOMY's Sky Guide for 1989. It's a guide you can scan right away for a taste of observing in the year to come — and then keep it close at hand for reference. It begins on page 78. Enjoy.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Running like Clockwork

The sidereal clock in "Build ASTRONOMY's Star Time Clock" by Irwin Sternberg (March 1988), plus the corrections in the June Letters, was a challenge because I had no experience with electronics. In addition, Canadian stores don't sell electronic digital clocks with the 50/60-hertz select option, so I ordered a clock from the United States.

After reading the article, I still had one question about the abbreviated notation in the circuit diagram. Following the advice in the March Behind the Scenes, I talked to a Radio Shack service center electronics engineer who answered my question in a minute.

Upon completion of the clock circuit modification and its perfect performance at the first plug-in and setting, I experienced the exhilaration that, I believe, must be similar to that of a scientist who puts his first satellite into orbit. — *Ted Plenert, Winnipeg, Manitoba*

Neighborhood Night Watchers

I've been an amateur astronomer for several years and I've wondered if anyone else has ever thought of this hobby as a crime deterrent.

Amateurs who spend long hours out at night can get a good view of the goings on in their neighborhoods and are in a prime position to contribute to their neighborhood watch programs.

I have notified the authorities on several occasions about thieves breaking into a nearby convenience store and have seen one burglar caught because of an alert observer.

We as amateurs can and do help in this area and should participate in our own local programs as much as possible. We can make a difference! — *Alan S. Miller, San Antonio, Texas*

A Handy Way to Focus

I have found a way to beat the whips and jiggles and the high cost of focusing motors for my Schmidt-Cassegrain telescope. Gross focus is done by hand, and then the rubber cup of a handy tool is slipped over the focusing knob for a very precise focus at high magnification. How well this homemade tool works depends on the overall stability of the telescope and mount as well as the tension/friction of the focus knob.

A tool like this would also work well on rack-and-pinion focusers, but I suggest the use of one on each side with the rods pointed in opposite directions to balance the pull on the scope.

This tool also works well on slow-motion control knobs or anywhere that shock absorption and mechanical advan-

"Your Eyepiece Has Given Me the Most Pleasant Case of Insomnia Imaginable"

Tom Lorenzin, author of "1000+ Guide to Deep Sky Observing"

Discover Type 2 Nagler Eyepieces

These new designs extend the Nagler concept to impressive new performance levels, while retaining the basic advances of the original Naglers:

—82° apparent field
—full field correction
—fast aperture correction, to f/4

TELE VUE 16MM NAGLER TYPE 2
TELE VUE 12MM NAGLER
TELE VUE 20MM NAGLER

New Features Include:

First: longer focal lengths produce wider true fields of view.
Second: full exit pupil correction permits comfortable night *and* day use.
Third: fold-down rubber eyeguards are included for maximum comfort and dark adaptation.
Fourth: they are relatively lightweight, moderately sized, and include knurled rubber grip rings for easier handling.

Design Goals

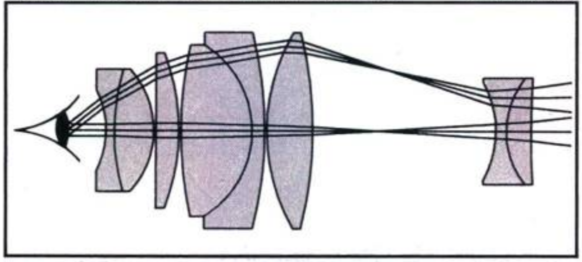
The basic Nagler series has already achieved image correction 10 times better than previous wide angle eyepieces (study in "Telescope Making" titled "The Nagler 13, a Remarkable Telescope Eyepiece"). We felt that extending the apparent field or image correction levels beyond that of the original Nagler series would *not* yield significant practical gains, but that extending the focal lengths *would* offer enormous potential for spectacular low power, wide-angle viewing.

In order to produce longer focal length Naglers, two practical limits had to be overcome:

1) Substantial physical size, weight, and cost increases would be impractical.
2) Scaling up exit-pupil aberrations would be unacceptable in our judgement. Although the 13mm Nagler eyepiece provides extremely sharp *images*, exit-pupil aberrations require a large (nighttime) eye pupil opening to encompass the full field. For this reason, daytime viewing with the 13mm Nagler is not recommended. Eye positioning is just too sensitive with the 7 element design to consider focal lengths longer than 13mm. The 9mm and shorter Naglers don't show this sensitivity.

Nagler Type 2: The design breakthrough!

The patented (#4,747,675) 8-element design achieves pupil aberration correction far beyond any eyepieces produced with such large apparent fields. Each model is a unique design, with eye relief similar to the 9mm Nagler, yet surprisingly compact, lightweight and affordable. Extensive computer-aided design efforts and the use of new glass types retain the superb full-field and fast aperture sharpness of the 7-element Naglers. Our pioneering lens edge-blackening and multi-coating techniques also maximize contrast.



A special rubber eyeguard aids viewing comfort, eliminating stray light and enhancing dark adaptation. This helps in detecting faint, delicate nebulosity and comets. The eyeguard is a delight on cold nights too.

20mm Nagler Type 2

Has the largest true field in the series. Yet this eyepiece, (strictly for 2 inch focusers) is comparable in size and weight to a 13mm Nagler. There's nothing like this 20mm for viewing large open clusters, galaxies and nebulae. It gives a 4.5mm exit-pupil with f/4.5 telescopes. Daytime viewing is also simply stunning!

16mm Nagler Type 2

Offers far more true field than the 13mm Nagler, yet is smaller and lighter. Great day or night performance with any telescope.

> *"There is nothing like this eyepiece (20mm Nagler) for viewing large deep-sky open clusters, galaxies, and nebulae. Under ideal conditions at Yosemite National Park, I was treated to incredible views of M8, M13, M17, M22, M31, and M33. I had believed that my C-8 would never perform visually with photographic quality, but my observations with the Nagler rivaled the detail in good astrophotography and even surpassed it at times. I was amazed and deeply satisfied. Thank you for the ultimate eyepiece."*
>
> Ben Cohen, CA

12mm Nagler Type 2

As superb as the 16mm, but with higher magnification. An excellent alternate to the 13mm Nagler, which has a longer eye relief for people who MUST wear eyeglasses to correct severe astigmatism.

The 16mm and 12mm Type 2 Naglers work beautifully with Tele Vue Barlows. These 1¼" barrel eyepieces can also be used with 2" focusers.

As Dr. Jack Marling says: "The eyepiece is half the telescope, so use the best... Tele Vue."

Tele Vue™

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WE'RE SERIOUS ABOUT HAVING FUN WITH ASTRONOMY.

tage are needed. Before I found a source for the rubber cups, some people were making their own versions of a tool like this with hex wrenches and screwdrivers. One person I know of even uses a 12-inch bamboo shish kabob skewer that he swears by. — *Michael Chesser, San Diego, California*

A HOMEMADE TOOL for focusing.

Are Sample-Return Missions Practical?

"The Soviets Advance into the Solar System" by Donald F. Robertson (July 1988) and other articles like it have been fanning the flames of a Mars sample-return hysteria.

It could be more practical to send an automated laboratory to Mars instead of bringing samples to Earth. This mobile lab could do all the analysis of Martian samples on Mars.

A sophisticated rover/laboratory combination could accomplish the same goals as a sample-return mission but would involve fewer launches and thus be less expensive. — *Eric Noevere, Virgin Gorda, British Virgin Islands*

Corrections

Your excellent article "Cosmic Origins of the Elements" by Gary Bennett (August 1988) contains a mistake in the diagram on page 19. One of the reactions shown is the collision of a neutron and positron to form an electron and a proton. This is not a possible reaction because charge is not conserved. The description of this reaction in the text of the story describes the products of such a collision as a proton and an antineutrino, which is allowed by charge conservancy. — *John W. Scott, Beaumont, Texas*

In "A Close-Up Look at Eyepieces" by David J. Eicher (October 1988) the labels for the Orthoscopic and Plossl eyepiece designs on page 86 were inadvertently switched. In addition, the way to determine the eyepiece's magnification should have been described as the result of dividing the focal length of your telescope by the focal length of an eyepiece.

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, *1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity.* ☐

Viewpoint

THE SELLING OF SPACE ASTRONOMY

by Robert W. Smith
Historian at the Smithsonian Institution's National Air and Space Museum and The Johns Hopkins University and author of the forthcoming book, Shaping the Space Telescope: The Interpretation of Science, Technology, and Politics *(Cambridge University Press, New York)*

Socrates: Shall we make astronomy the next study? What do you say?

Glaucon: Certainly. A working knowledge of the seasons, months, and years is beneficial to everyone, to commanders as well as to farmers and sailors.

Socrates: You make me smile Glaucon. You are so afraid that the public will accuse you of recommending unprofitable studies.

In this exchange from Plato's *Republic*, Socrates identified an issue that still dominates astronomy today, especially astronomy conducted from space: the dependence of astronomy on the will of the public. Like it or not, extrascientific pressures inevitably play a major, if not a dominant role in decisions concerning science projects, especially the "big science" projects funded by the public treasury. Science alone is no longer enough to win sufficient political support for big projects like the *Hubble Space Telescope*, if indeed it ever was.

Major space astronomy projects have proven so costly that to date only the federal government has been able to provide the funds. The *Space Telescope*, in many respects the most ambitious astronomical project ever undertaken, has already cost $2 billion. These costs alone are enough to force the patrons of big science — the White House and Congress — to scrutinize these projects.

As a result, proponents of big science projects have to adopt Glaucon's concern for winning public approval and do whatever politicking is necessary. The *Space Telescope* was approved in 1977 only after years of effort. It followed intense lobbying campaigns in which astronomers played major roles.

Before this time, only the leaders of astronomy had done the politicking. The various lobbying campaigns for the *Space Telescope*, in contrast, involved many astronomers who visited, made telephone calls, and wrote letters to Congressmen and their staffs, planted articles in newspapers and journals, formed links with industry representatives, and so on. There was, in effect, a massive effort to sell the idea of the *Space Telescope* to its potential buyers and patrons.

The policy-making process that produced the *Space Telescope* involved the complex and sometimes downright confusing interplay of many different interests. The astronomical community was just one interest, but its concerns had to be balanced against those of industry and government.

In particular, it was a process in which the fundamental question of what the *Space Telescope* would be was constantly being reframed and repackaged. The telescope designs and the program to build it were also revised and rebundled, in part by the demands of making the telescope more politically feasible. To win the backing of the White House and Congress, as well as to make the program more attractive to NASA, the telescope was linked with the space shuttle program, both as the telescope's launch vehicle and in-orbit maintenance system.

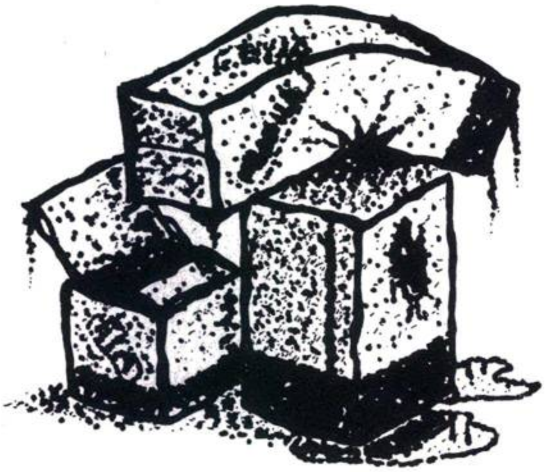
Science alone is no longer enough to win political support for "big science" projects.

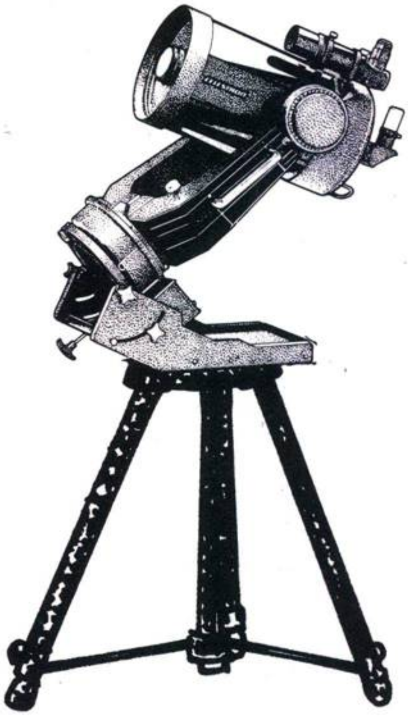
Although the redefinition of the *Space Telescope* and its associated programs involved detailed engineering analyses, equally important were the financial analyses that NASA and its contractors made in light of what the "market" — in the form of Congress and the White House — would bear. If NASA proposed a telescope that was deemed too expensive, the project would be killed. In the process the size of the primary mirror was reduced and an international partner, the European Space Agency, was added.

The whole policy-making process is best described as an "ad-hocracy," in which policy is hammered out in a variety of arenas according to ever-shifting rules and players and in which no one ever has a complete grasp of what is happening. An ad hoc policy process is certainly a long way indeed from the sort of "rational" policy-making that is often presumed to operate.

Whether space astronomers like it or not, the billions of dollars that have gone to their discipline from the federal government means they have long lost overall control of their activities. ☐

This Christmas, which Ultima would *you* rather buy?





Would you buy a car from a catalog? Of course not—you'd want to test drive it first. And, if you're really smart, check out the dealer just as much as the car. After all, the flashiest sports car is no good if the parts and service you need are in Stuttgart, while you're stuck in a ditch outside St. Paul.

So why is it so many people are willing to take that kind of risk when buying a telescope?

With a telescope often costing the better part of two thousand dollars, a few of us dealers believe that the least you should do is drive it around the block (figuratively speaking, of course). And, since we stock and display the equipment we sell, we don't mind a bit if you just want to come in and kick the tires.

See, ask about, and touch astronomical equipment at these locations–

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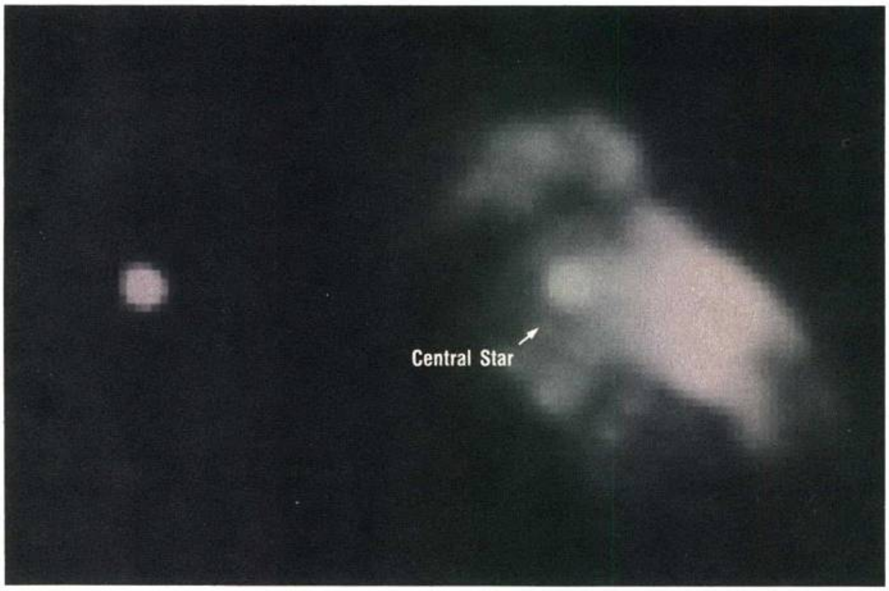
MYSTERIOUS CENTRAL STAR IDENTIFIED



THE CENTRAL STAR of NGC 7027 glows to the left of the bright nebular blob in this photo taken through the 3.6-meter Canada-France-Hawaii Telescope on Mauna Kea. The "smoky" area shows the outer regions of the nebula.

Astronomers love a mystery, and for many years NGC 7027 has provided them with a good one. Undoubtedly one of the most studied planetary nebulae, NGC 7027 has aroused astronomers' curiosity for years because it is not like most other planetaries: it is dusty, rich in carbon monoxide and, more important, its central star, embedded deep within the dense nebula, has evaded identification. Because astronomers haven't known what type of star produced the nebula, their attempts to understand the nature of this object have been thwarted.

But it is a mystery no more. George H. Jacoby of Kitt Peak National Observatory reported in the *Astrophysical Journal* (October 1, 1988) that he has identified the central star of this nebula. His research confirms that NGC 7027 is a young planetary nebula between two thousand and three thousand years old.

A planetary nebula is an expanding shell of gas that has been blown off by a dying star, a red giant in the late stages of its evolution. Many planetary nebulae look like rings or hourglasses of gas surrounding a bright central star. The gas surrounding the star is made to glow by the central star, the hot stellar remains of the red giant. Compared to emission nebulae like M42 in Orion, planetary nebulae have brief life spans, about 50,000 years or less.

NGC 7027, however, is an atypical planetary nebula for a number of reasons. It contains a lot of internal dust, which is why the planetary emits an excessive amount of infrared radiation. The planetary is also surrounded by a shell of neutral gas, that is, gas not ionized by the central star. And the nebula has an inordinate amount of carbon monoxide, about ten to twenty times as much as most other planetaries.

"All these things would be predictable today if we knew more about young planetary nebulae twenty years ago, before the observations were made," said Jacoby. "Now we can say 'yes, these characteristics are predictable because this is a young planetary nebula and so the dust hasn't been blown away and the neutral gas hasn't been ionized yet.'"

Jacoby obtained images of the nebula by using a charge-coupled device and a 36-inch telescope at Kitt Peak. The object's nebular emission was then digitally "subtracted" to bring out the star. Once the star was identified and an apparent magnitude derived (16.3), the related physical characteristics could be determined. Most important among these are luminosity and temperature, because these are bench marks of the star's evolution.

The star's temperature is about 180,000 kelvins and its mass is 0.65 solar mass, which is not as massive as many astronomers thought. The star's diameter is about 62,000 miles, slightly smaller than Saturn. Nevertheless, it is 4,900 times more luminous than the Sun.

An added twist to this story has been added by Sara Heap, an astronomer from NASA's Goddard Space Flight Center in Greenbelt, Maryland. Heap reports that she and colleague Eric Smith have observed the central star of NGC 7027 *without* subtraction procedures using the 3.6-meter Canada-France-Hawaii Telescope at Mauna Kea, Hawaii.

"The seeing is so good on Mauna Kea," Heap said, "you don't need image-subtraction techniques. The whole thing looks like a 24-carat diamond ring with the diamond being a nebular blob. And in the middle of the ring is the central star."

Heap said that she and Paul Hintzen, also from Goddard, have, in addition to confirming Jacoby's findings, also located the elusive central star in another dense but more highly ionized planetary nebula, NGC 2440, using a subtraction technique similar to Jacoby's.

PLUTO IS RED, CHARON IS GRAY

Pluto is covered in a layer of reddish methane ice, except for polar caps of white ice, said Richard Binzel, astronomer at MIT. Pluto's moon Charon, however, is essentially gray in color.

Writing in *Science* (August 26, 1988), Binzel reported that observations made with the 107-inch telescope at McDonald Observatory in Texas produced blue (B) and visual (V) magnitude measurements of the system while Charon was in total eclipse behind Pluto.

Subtracting an object's visual magnitude from its blue magnitude gives a number that is numerically larger for redder objects. With Charon out of sight behind it, Pluto alone had a B-V magnitude of 0.87. Because the Sun's B-V magnitude is 0.65, Pluto evidently reddens sunlight reflecting from it. When Binzel reworked the results to derive Charon's B-V magnitude, it came out to 0.70 — so close to the value of sunlight that Charon must appear neutral gray.

Binzel suggests that his observations support a model for Pluto that has a polar cap of fresh, unreddened frost over at least part of the northern hemisphere. (When Charon begin transits of the southern hemisphere in 1989 or 1990, astronomers will be able to see if Pluto

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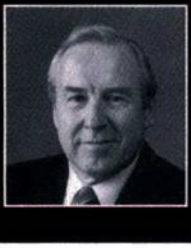

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has a southern polar cap as well.) Within the precision of Binzel's observations, the northern cap turned out to have the same color as Charon, but he cautions against assuming that Charon and the polar cap are covered with the same material.

A bright polar cap and darker equatorial zone are products of Pluto's annual cycle, claim three astronomers reporting in *Icarus* (September 1988).

Alan Stern of the University of Colorado at Boulder, Laurence Trafton of McDonald Observatory, and Randall Gladstone of the University of California at Berkeley write that ultraviolet light from the Sun, galactic cosmic rays, and the impact of protons in the solar wind all darken and redden Pluto's methane-rich surface material by creating organic polymers and "tars" from the methane and its by-products, ethane, acetylene, and ethylene.

As Pluto approaches perihelion during each of its years, a thin methane atmosphere sublimates from the frosts and ices at the surface. The creation of this atmosphere tends to darken the planet as the tarry surface material is left exposed when the frosts covering the surface evaporate. Stern and his co-workers note that between 1955 and now, Pluto's reflectivity has dropped from about 75 percent to 55 percent.

After its perihelic summer passes, Pluto's temperature drops and the atmosphere begins to freeze out, depositing a fresh, bright coating of methane frost over the dark polymerized surface. The astronomers predict that we will begin to see Pluto's albedo brightening again about seven to seventeen years after perihelion. (The delay is caused by the fact that Pluto's temperature won't drop immediately.) They also predict that when the *Space Telescope* begins to observe Pluto's disk, the bright areas on Pluto will grow and the surface will become more neutral in color.

DIRECTOR OF MCDONALD OBSERVATORY HONORED

HARLAN J. SMITH, director of McDonald Observatory, and the dome of the 107-inch telescope on Mount Locke in west Texas.

University of Texas astronomer Harlan J. Smith, under whose guidance McDonald Observatory and the UT astronomy department have flourished over the past quarter of a century, was honored this fall at the university's Frank Erwin Center. Smith, who paved the way for the building of the 107-inch telescope, was praised as a man whose vision, energy, and hard work provided the impetus for progressive changes at McDonald Observatory.

Smith first came to the University of Texas in 1963. At the time the astronomy department consisted of four faculty members and four support employees. It was a pivotal time for the department. McDonald Observatory, located in west Texas on Mount Locke, had just become the sole responsibility of UT following a thirty-year partnership with the University of Chicago.

One of Smith's first projects was to refurbish the 82-inch telescope, completed in 1938. This instrument is still in use today. However, Smith was convinced that the dark, clear skies at the observatory site were conducive to high-quality astronomical research. Thus, in 1965 Smith enlisted the support of NASA, the National Science Foundation, and the university to construct a 107-inch telescope. This instrument was completed in 1969 and was the third largest in the world at the time.

During Smith's tenure, McDonald Observatory has also branched out into radio and millimeter-wave astronomy. The University of Texas Radio Astronomy Observatory (UTRAO) occupies four square miles of west Texas landscape, south of the main observatory. The UTRAO is nearing the completion of a survey of the radio sky from −35° to +90°. Once completed, it will include about 80,000 sources with positions accurate to one arcsecond, the largest such catalog ever made.

During his next twenty-five years Smith hopes to see a new telescope on Mount Locke. Last January UT announced that it had joined forces with Penn State University to construct the Spectroscopic Survey Telescope. The proposed telescope's segmented mirror will equal the light-gathering power of a single 320-inch mirror. This will in turn allow astronomers to collect light from distant quasars and galaxies and to study their spectra in greater detail than before.

Smith's efforts have paid off not only for McDonald Observatory but for the UT astronomy department as well. Today the department has nearly two dozen faculty members and an almost equal number of research astronomers covering virtually every realm of astronomy from planets to cosmology.

DO METEORITE AGES TELL OF COMET STORMS?

When planetary scientists examine one kind of meteorite rich in iron, the H-chondrites, they find that the meteorites' ages do not spread evenly through time. Instead, the ages appear to cluster at 7 million and 30 million years.

Writing in the May 1988 *Icarus*, Saul Perlmutter and Richard A. Muller of the University of California at Berkeley propose that these ages mark when "storms" of comets entered the inner solar system from the Oort cloud and smashed into both the asteroid belt (the ultimate source for nearly all meteorites) and Earth.

Every meteorite that falls to Earth was once part of some larger object. Broken loose from its parent body by collision, a meteorite will drift around in the solar system until its orbit happens to intersect Earth's orbit. While still buried in its parent body, the meteorite is protected from cosmic rays. But when the parent body breaks open, the rays begin to make detectable changes in the nuclear structure of the meteorite's surface. The more such changes found in a meteorite, the longer the time that has passed since the meteorite's parent body was broken apart.

The standard explanation for the clumped ages of H-chondrites has been

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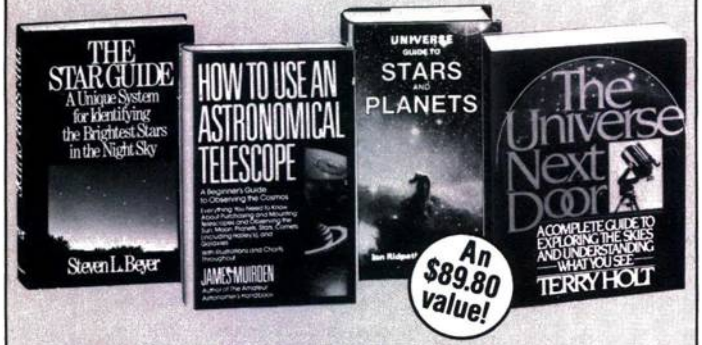
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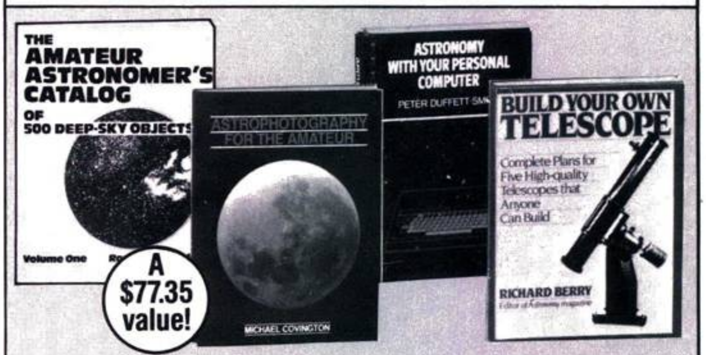
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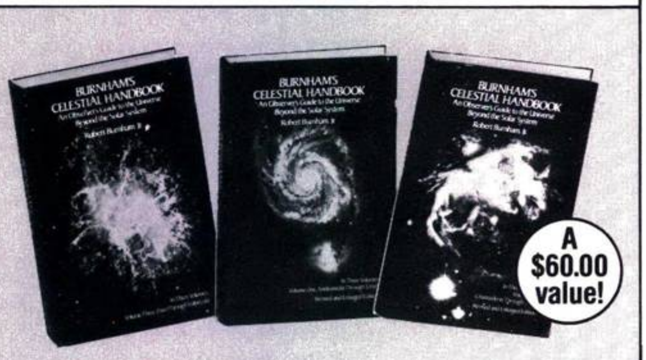
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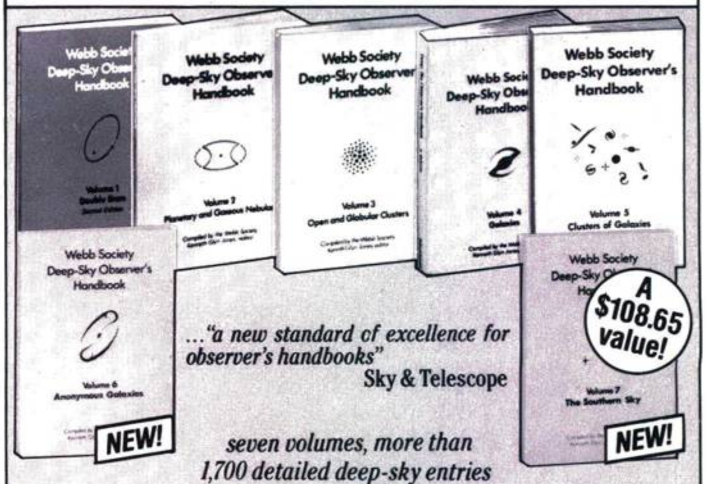
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Astronomy 1/89

that meteorites come from collisions between their parent bodies and other asteroid belt objects. The California scientists point out, however, that several independent lines of evidence point to impact events on Earth at these times also.

For instance, the fossil record shows signs of a 26 million- to 30 million-year periodicity in extinctions. Many of the theories that attempt to explain this repeated pattern involve comet storms, periods when unusually large numbers of comets would be dislodged from the Oort cloud by the gravity of passing stars. The comets would "rain" down on the inner solar system, hitting planets and moons alike and leaving much destruction in their wake.

Other evidence for periodic disturbances on Earth includes the rate at which the polarity of the terrestrial magnetic field reverses itself. These changes occur with greater frequency at approximately 30 million-year intervals. Terrestrial cratering, too, shows bursts of activity that match the extinction events, as witnessed by enrichments of rare elements such as iridium that have been found in the fossil record.

Muller and Perlmutter note that the 7 million-year age for the H-chondrites does not appear as an instantaneous event. (Neither does the 30 million-year event, but the samples are fewer.) Instead, the recent period of formation for these meteorites lasted almost 4 million years. This duration also agrees with comet storm theory, which calls for the influx of comets to begin slowly, build to a maximum, and then die away as the comets are swept up by the planets without replenishment.

MOUNT WILSON PROGRAMS TO BENEFIT FROM CALENDARS

The Mount Wilson Institute is selling 1989 calendars to raise funds that will help establish educational and public programs at the Mount Wilson Observatory. The observatory's 100-inch telescope was closed down in 1985, and the Mount Wilson Institute has been seeking support to reopen the telescope (see "Renaissance on Mount Wilson" by Richard Berry, April 1988).

The calendar features historical photos of the Mount Wilson Observatory and is available for a $10 donation plus $2 for shipping. Calendar orders and requests for information about becoming involved with the institute should be sent to the Mount Wilson Institute, Box 60947, Pasadena, CA 91106.

Space News

DO THE SOVIETS NEED A SHUTTLE?

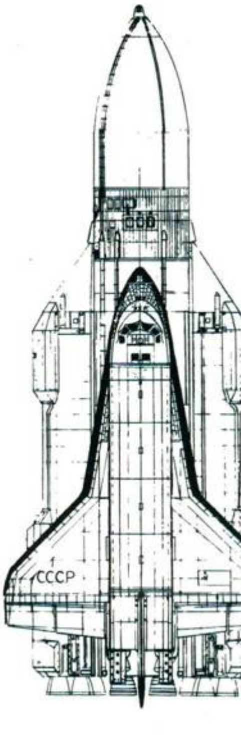
The Soviet Union's stable of more than a dozen operational vehicles for getting people and things into space now includes a vehicle not too unlike the U.S. space shuttle. Though their shuttle is on the pad ready for launch, the Soviets still haven't revealed what they plan to use it for.

The first launch attempt on October 29, 1988, was aborted by computer only seconds before liftoff because of irregularities in a launch support system. No new launch date was given.

In the last few years details on the Soviet shuttle have been emerging with greater frequency. This has been in part the result of *glasnost* and in part the result of the difficulties inherent in hiding a 100-ton shuttle from spy satellites. This climaxed in September 1988 just before the launch of the space shuttle *Discovery*, when photographs of the Soviet shuttle were released to the West.

At first glance it seems to be a near-twin of the U.S. shuttle orbiter. Some observers describe it as "armored" — no doubt this appearance is an aspect of its heat shield "tiles." Closer examination reveals more fundamental differences. Unlike the U.S. shuttle, there are no main engines attached to the Soviet shuttle. The main engines are instead part of the Energia heavy-lift booster that launches it. While it has been suggested that portions of Energia are salvageable after flight, the main engines are probably not among these.

THE SOVIETS have a shuttle, but what do they need it for?



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Throwing away the main engines after a single use may seem wasteful, but in fact it is a cheap solution to a frightfully complex engineering problem: devising low-cost yet reliable shuttle engines. The United States opted for reusability, a path that has had mixed results. After an expensive and time-consuming development program, the U.S. shuttle main engines are only good for a few flights before they require overhaul or replacement. The Soviets have opted for using proven expendable engines that are mass-produced to cut costs.

After *Challenger*, Soviet spokesmen declared that their first shuttle flight would be automatic, with no crew aboard, in an effort to demonstrate that the Soviet space program was more safety conscious than the American program. This past summer as the time for the launch of *Discovery* neared, the Soviets announced that their first shuttle flight would carry a two-person crew. But, by the time the first flight was ready for launch, that decision had been reversed and the flight was to be unmanned.

Probably the biggest mystery about the Soviet shuttle — and the one that may take the longest to resolve — is what it will be used for. The Soviets already have operational hardware that allows them to do everything the U.S. shuttle can do and more. They have a reliable manned spaceflight system *Soyuz*, a space tug/tanker/cargo ship *Progress*, an orbiting research base (*Mir*), and a variety of proven expendable boosters.

James Oberg, a noted expert on Soviet spaceflight, has argued that the Soviets might use their shuttle to return processed materials from a future Soviet space *industrial* complex. However, the Soviet Union already has at its disposal unmanned re-entry capsules, which it uses to return film and biosatellite experiments to

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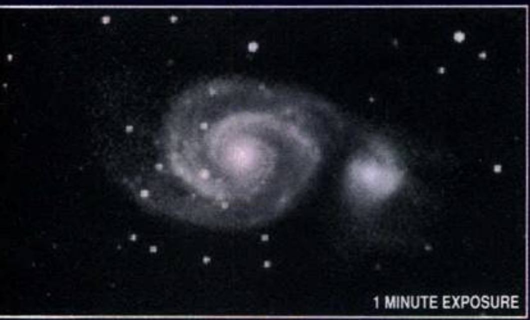

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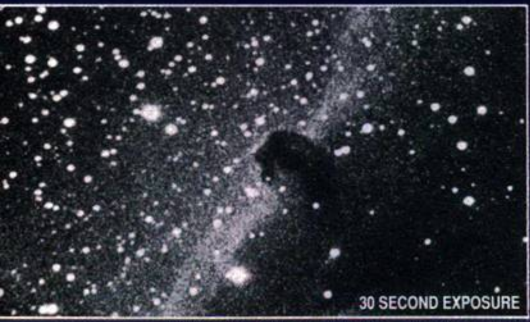

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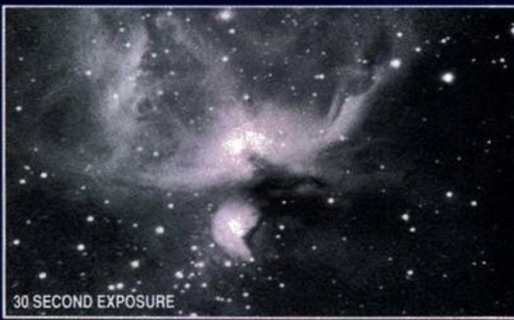

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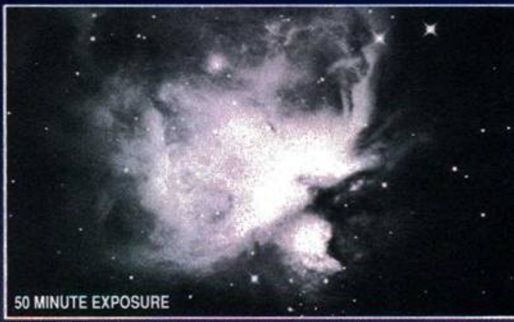

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Earth. A variation on these could serve the space cargo return needs of the Soviet industrial complex far more cheaply than a shuttle for the foreseeable future.

For the present, the number of Soviet shuttle flights will be limited by Energia's estimated one-per-year launch rate. However, based on satellite photographs, it is believed that the Soviets may have more than three orbiters. Whatever they want them for, the Soviets clearly want to be sure they are not caught short. — *David S. F. Portree*

SOVIETS LOSE CONTACT WITH PHOBOS 1

The Soviet Union has been unable to re-establish contact with *Phobos 1*, one of the two spacecraft launched last July to investigate the Martian moon Phobos. Though the two *Phobos* craft are very similar and carry some of the same experiments, the Soviets lose the ability to compare the data collected by the fixed-site landers both craft were equipped with and to study some of the surface characteristics of the moon with a radar experiment carried only by *Phobos 1*.

Because of erroneous programming instructions sent to *Phobos 1*, the craft was unable to orient itself with the Sun and thus lost power and the ability to receive commands.

The original *Phobos* mission called for close flybys of Phobos by both craft and deployment of fixed-site landers by each craft and of a mobile "hopper" lander by *Phobos 2*. The fixed-site landers were expected to operate about three miles apart for a year on the surface of Phobos. Both spacecraft also carry other instruments developed by the Soviet Union, France, and West Germany, including charge-coupled device cameras to image Phobos' surface.

One instrument only on board *Phobos 1* was a Soviet radar system designed to study the surface relief of Phobos and provide data on the moon's subsurface and the electrophysical characteristics of the soil. *Phobos 1* was also going to observe the Sun in conjunction with the U.S. *Solar Maximum Mission* for the first stereoscopic Sun images. Although the craft did return images, the coordination with *Solar Max* had not yet begun when contact was lost.

Phobos 2 has not been affected by any communications problems and will fly by Phobos in the spring of 1989. Because the second spacecraft no longer needs to wait for the first to complete its flyby, the flyby date for *Phobos 2* may be moved up by several weeks.

Amateur News

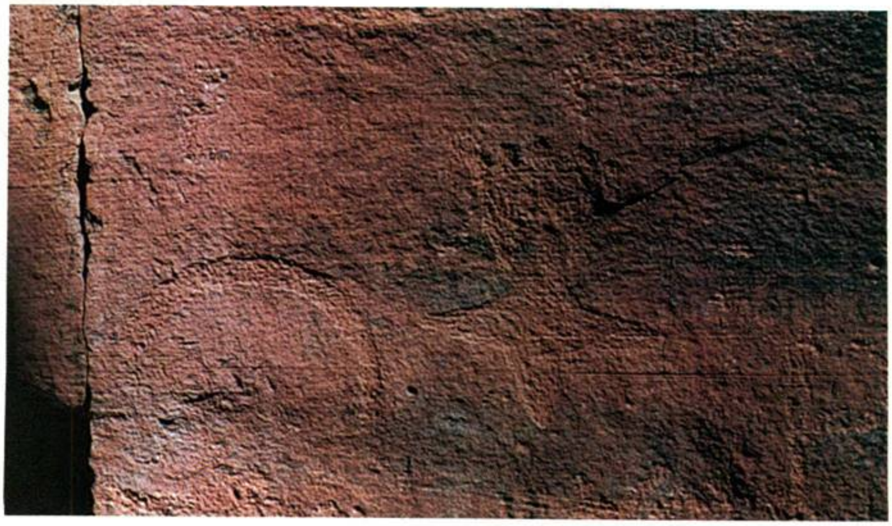
AMATEUR ASTROARCHAEOLOGISTS

Last April a group of amateur astronomers from Illinois had the unusual opportunity to study an ancient Indian site in New Mexico. Jack Kramer and seven colleagues surveyed the Tenabo archaeological site in central New Mexico, a pre-Columbian Indian dwelling that may have been used as an astronomical observatory. Remarkably, Kramer and his colleagues have found a star and Moon petroglyph that may refer to the Crab supernova in A.D. 1054. Also remarkable is the fact that the research group is not made up of professional archaeoastronomers but of amateur astronomers from the Lake County Astronomical Society near Chicago.

The club's study of Tenabo began when Lake County members started spending observing vacations in the high desert of New Mexico. Kramer and others met and befriended Glenn Fulfer and Tom Carroll of the National Park Service, who knew about a nearly forgotten Indian site supposedly used as an observatory hundreds of years ago. The site belongs to the Department of the Interior's Salinas National Monument Unit, but it is closed to the public for preservation purposes. When asked to get involved, the amateurs "jumped at the opportunity, hoping to contribute something useful to the field of archaeoastronomy," said Kramer.

In April 1988 Lake County members visited Tenabo and surveyed the site. Using a transit, they recorded positions of various rock features in Tenabo's approximately 170-by-120-yard dimensions. The site consists of a circular group of stones located in its center; similar groups to the east, north, and south; and rock "pillars" strategically placed throughout. After studying the alignments of the rock groups they surveyed, the Lake County amateurs confirmed what park officials suspected: many of the rock pillars and circles of stones appear to form alignments of astronomical significance. That is, various pillars are oriented in the correct azimuths to mark the rising and setting positions of the Sun, Moon, and bright stars.

But the biggest surprise came when Lake County members found a petroglyph — a picture chiseled in rock — at Tenabo that shows a crescent Moon and a bright star or comet. The group has no way of knowing for sure, but the petroglyph might represent an observation of the Crab supernova. (When the supernova became visible in 1054, a crescent Moon lay nearby.) Griffith Observatory astronomer Edwin Krupp, an expert on archaeoastronomy, believes a similar petroglyph at the nearby Abo site may show



A MOON AND STAR PETROGLYPH at the Tenabo archaeological site in central New Mexico may be an Indian depiction of the Crab supernova event.

the Crab supernova.

Whether or not the petroglyph is astronomically important, Tenabo deserves further exploration. "On-site analysis showed us that the Tenabo features were constructed with human hands and possibly for the purpose of observing stars," Kramer summarized. "Without further investigation, however, we don't know when the site was occupied or exactly why the occupants built it."

CALIFORNIA AMATEURS OPERATE 30-INCH TELESCOPE

In the summer of 1986 a group of amateur astronomers in the San Francisco Bay area began operating its own 30-inch f/4.8 telescope in Fremont Peak State Park, about fifty miles south of San Jose, California. Fremont Peak offers reasonably dark skies relatively near major metropolitan centers. Last summer the amateurs began conducting research with the telescope and have continued to make it available for public star parties and observing nights for school groups.

The 30-inch telescope project began in 1980, when California telescope-maker Kevin Medlock purchased a 4-foot-by-3-foot piece of Pyrex glass. Medlock cut, ground, and polished the mirror and built the 30-inch telescope, but he had no site dark enough to make use of its great light-gathering power.

Then came Fremont Peak. The state park on Fremont Peak had been a popular observing spot for some twenty years, but by the early 1980s the California state government considered closing the park because it wasn't used much by the public. In 1984 Medlock and friends contacted the state Parks and Recreation Department and offered to build an observatory on Fremont Peak. The state accepted. On January 1, 1985, Medlock and friends formed the Fremont Peak Observatory Association and raised $23,000 to build the observatory.

Fremont Peak Observatory was dedicated on August 1, 1986, and the observatory building was officially given to the state of California in May 1987. Public observing now takes place every Saturday night except for nights near Full Moon. Friday nights are reserved for civic and school groups.

Having successfully built the 30-inch telescope, Medlock and friends are now thinking about building a 70-inch telescope for public observing. They have located a mirror blank and hope to construct the world's largest amateur telescope over the next several years. — *Robert A. Garfinkle* ☐

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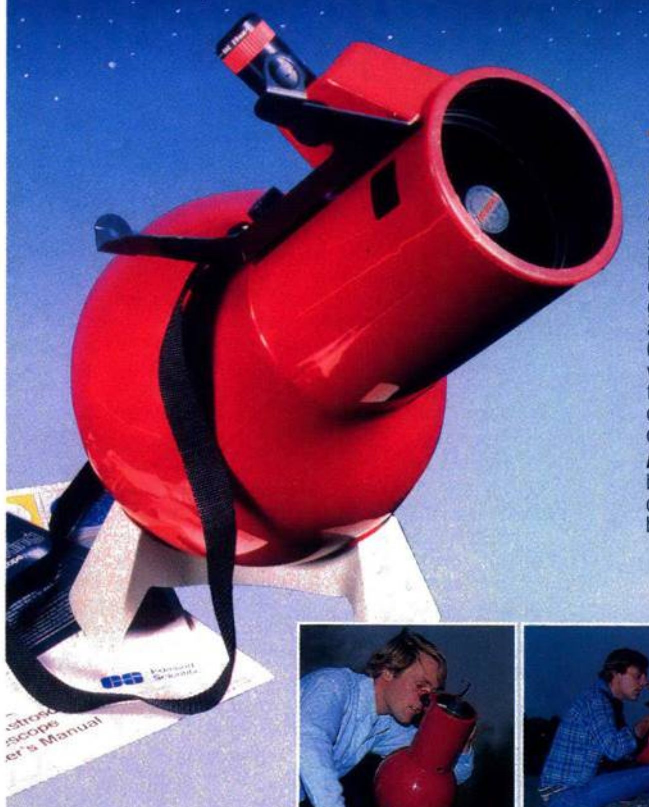

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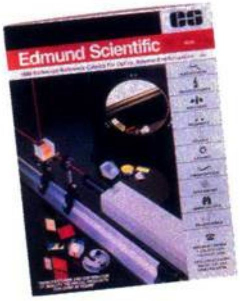

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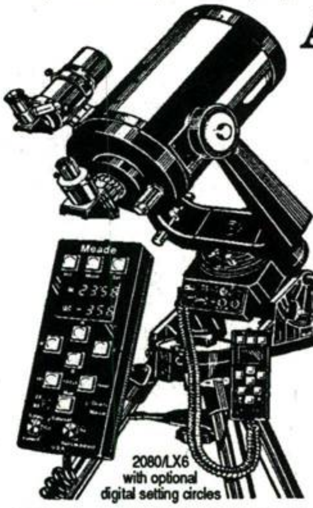
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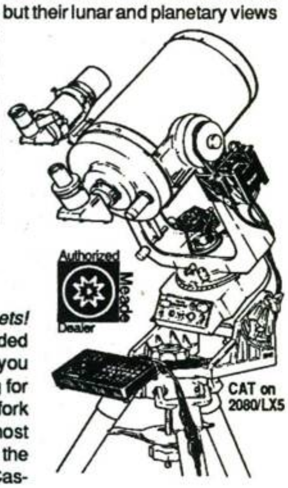

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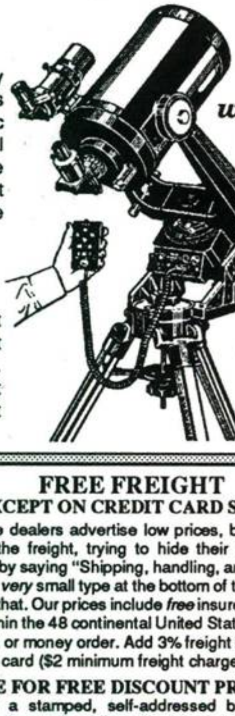
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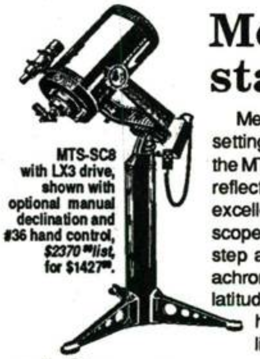
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The CAT, shown on a Meade Model 2080/LX5.

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Warranty: Every Meade CAT and DSC unit is covered by a 3-year warranty on parts and labor.

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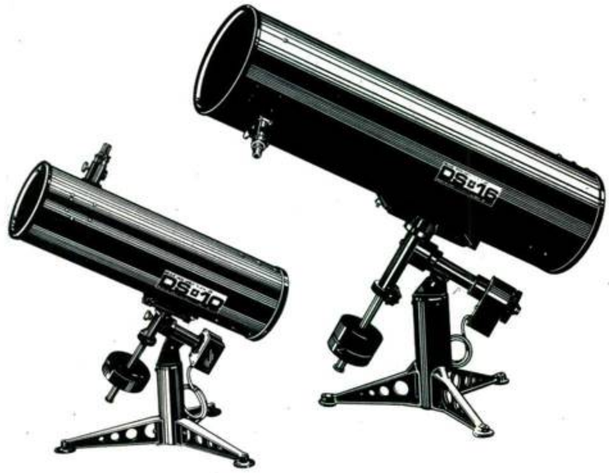

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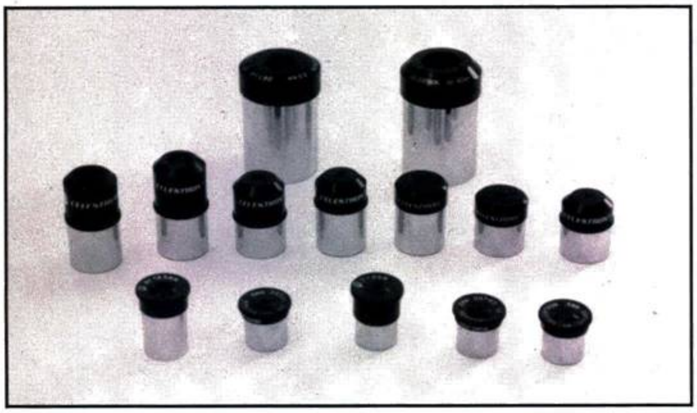

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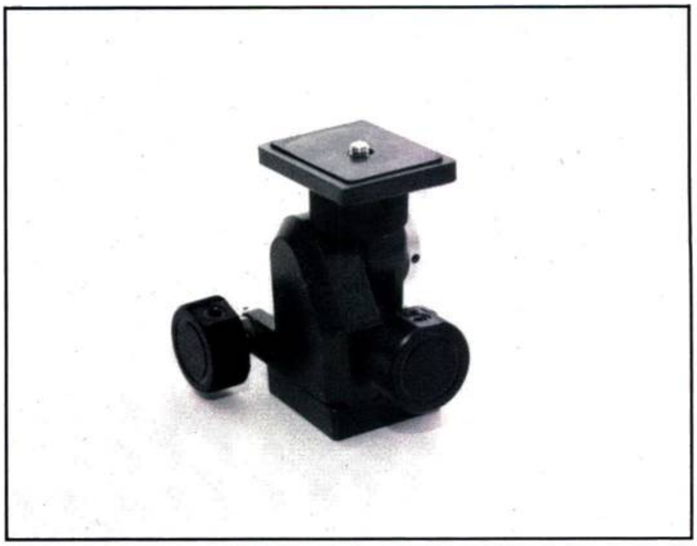

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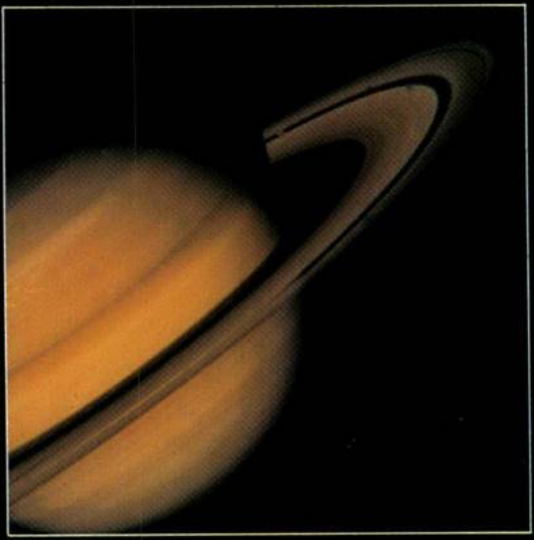
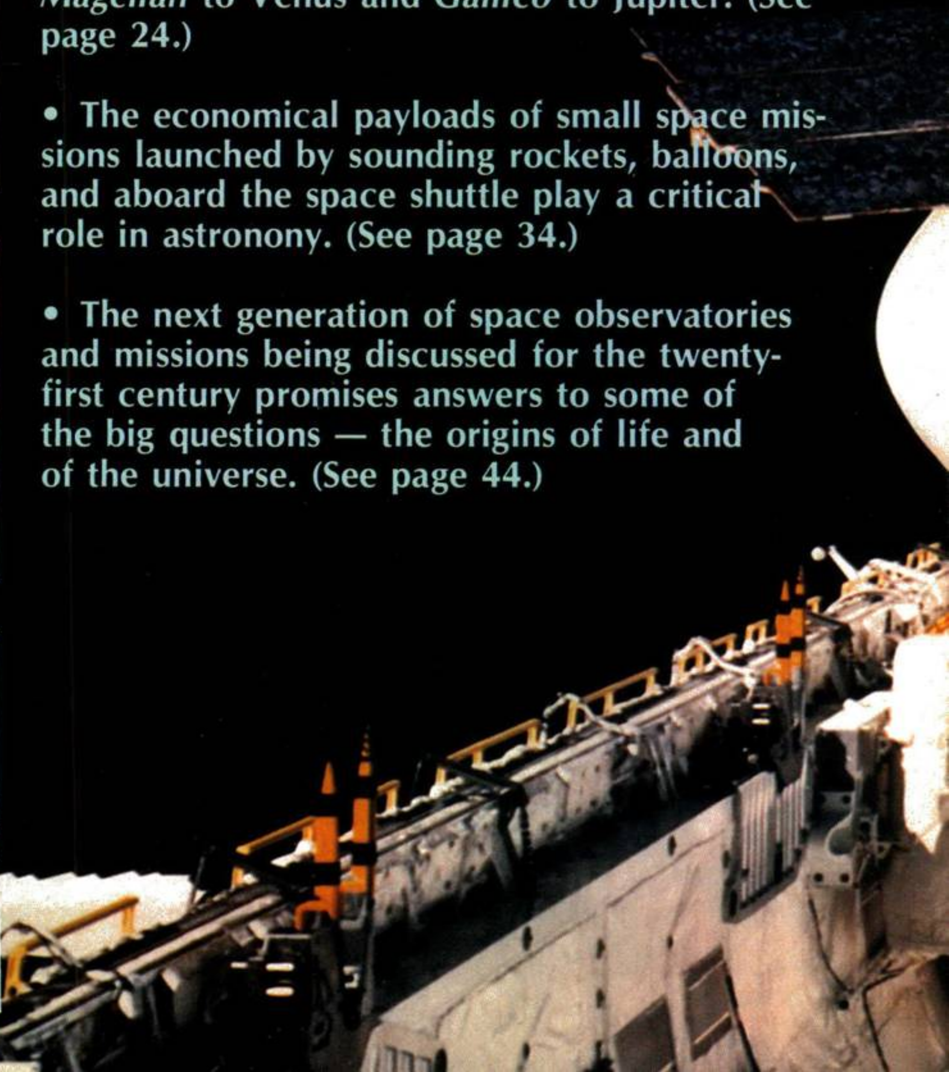


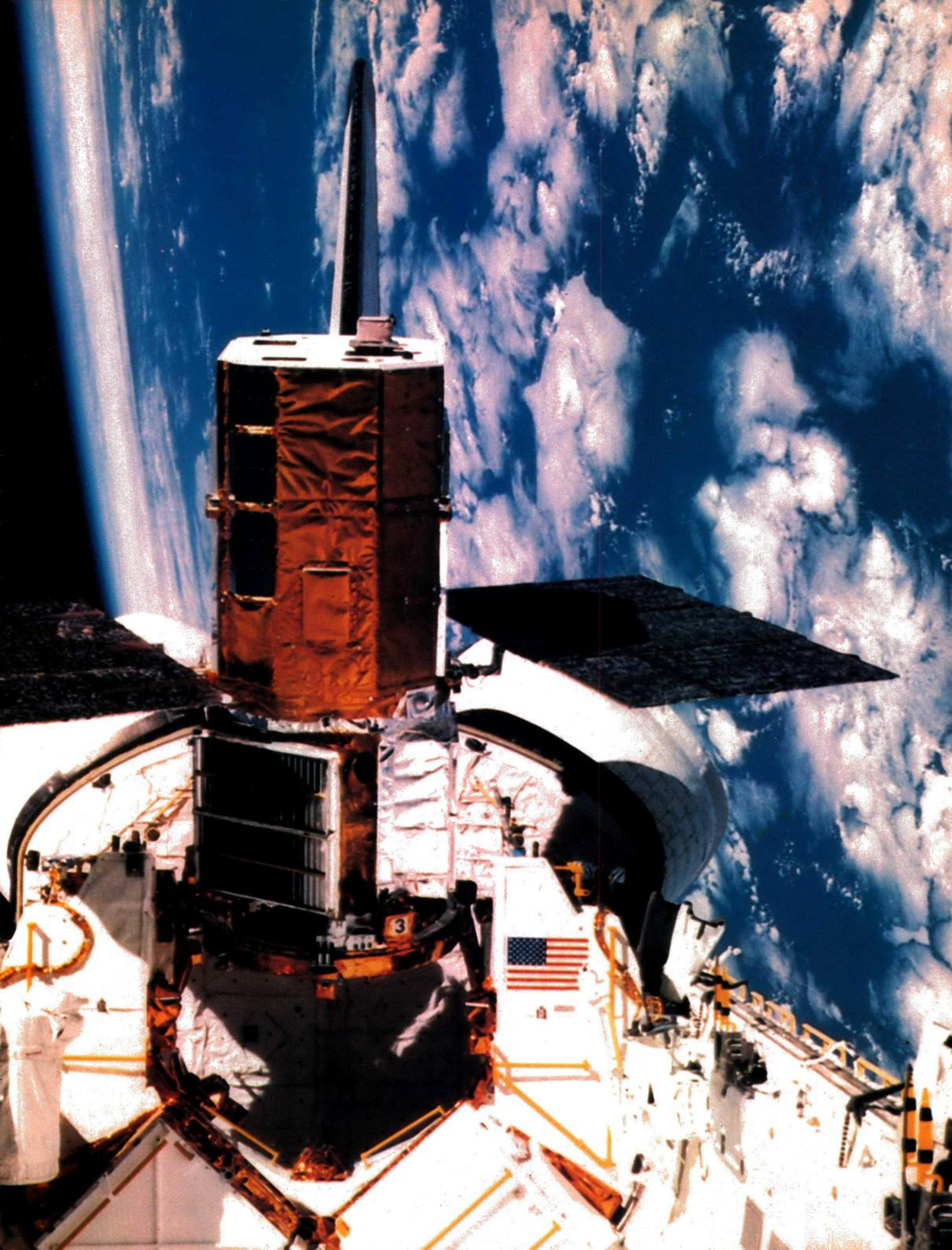
The United States has returned to space. After nearly three years devoted to getting the space shuttle back in operation, the country is ready to get back to the business of exploring the solar system and the universe from space.

- **At long last the United States returns to the planets this year with two large-scale missions, *Magellan* to Venus and *Galileo* to Jupiter. (See page 24.)**

- **The economical payloads of small space missions launched by sounding rockets, balloons, and aboard the space shuttle play a critical role in astronony. (See page 34.)**

- **The next generation of space observatories and missions being discussed for the twenty-first century promises answers to some of the big questions — the origins of life and of the universe. (See page 44.)**

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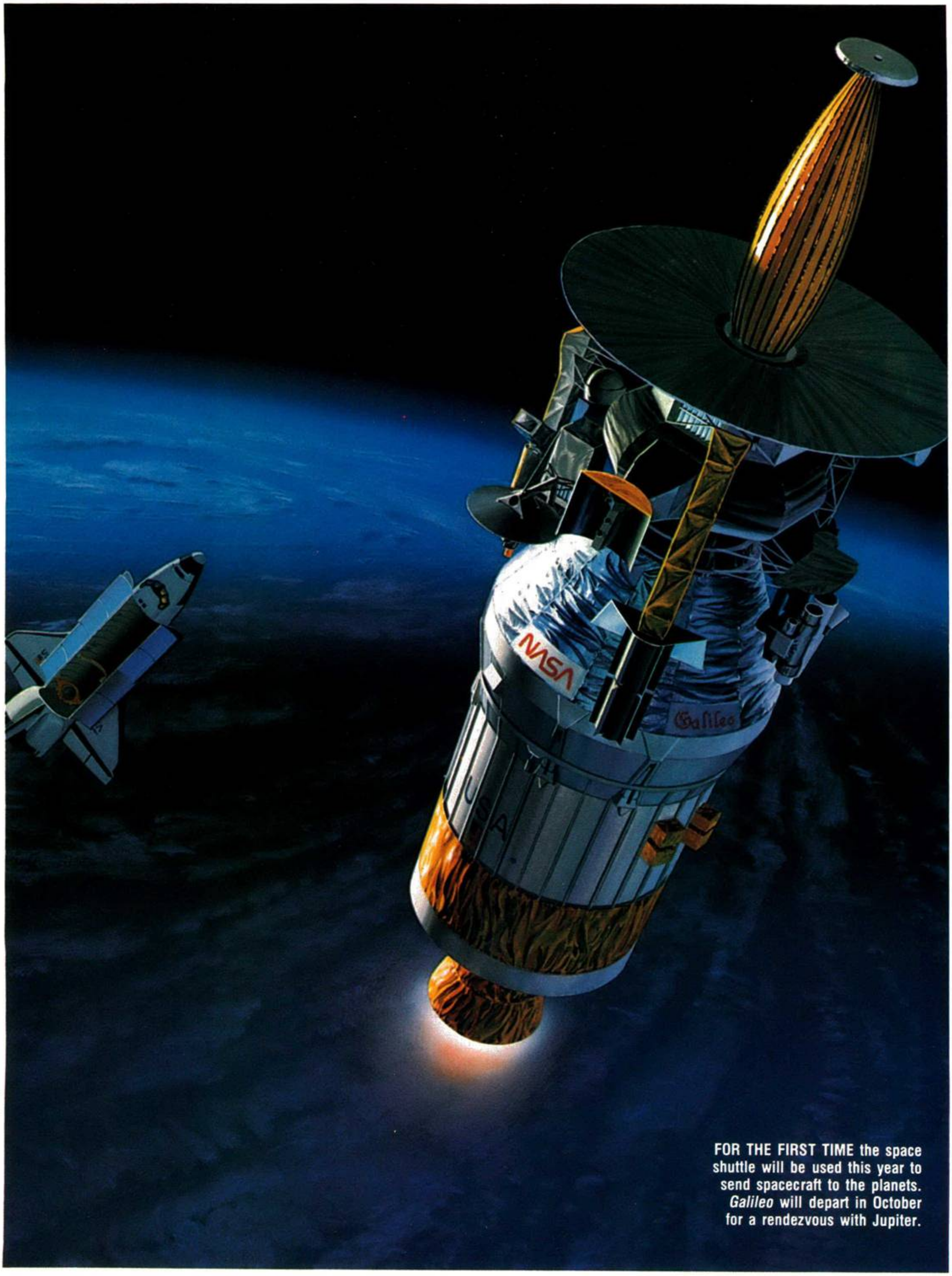


FOR THE FIRST TIME the space shuttle will be used this year to send spacecraft to the planets. *Galileo* will depart in October for a rendezvous with Jupiter.

REDISCOVERING VENUS AND JUPITER

Magellan's state-of-the-art radar mapping of Venus and *Galileo*'s intricate flybys through the Jovian system will give us the best look yet at these planets.

by Stephen Cole

The last time the United States sent a spacecraft to explore the solar system; you had not used a word processor in your daily work, you had never heard a digitally recorded note in your home, and you had never seen a space shuttle fly. The technological dark ages of the late 1970s, however, produced spacecraft that put us on the surface of Mars and sent us on a decade-long cruise to Jupiter, Saturn, Uranus, and Neptune. Seventies technology produced a decade of exploration that, with its astounding breadth and number of discoveries, left us with the impression that we must certainly have seen it all.

But later this year a new generation of technology will get its chance to show us that "we ain't seen nothing yet." This April the space shuttle is scheduled to send its first planetary mission toward Venus to do what no other spacecraft has done: produce a global map that will reveal fine-scale surface features hidden below the planet's constant cloud cover. Then in October another spacecraft begins its voyage to Jupiter for a two-year-long study of the atmosphere and satellites of this gas giant planet.

Both missions — *Magellan* to Venus and *Galileo* to Jupiter — represent technological advances over previous missions to these planets. These are not follow-up missions that will just fill in a few of the pieces missed by earlier probes. These missions will produce a quantum leap in our understanding of both planets.

"*Magellan* will give us better surface images of Venus than we have now of Earth," said William T. K. Johnson, the Jet Propulsion Laboratory engineer who designed the mission's radar. "The mountain of data we'll get back will take decades to analyze. We won't need to send another radar to Venus after *Magellan*," said Johnson.

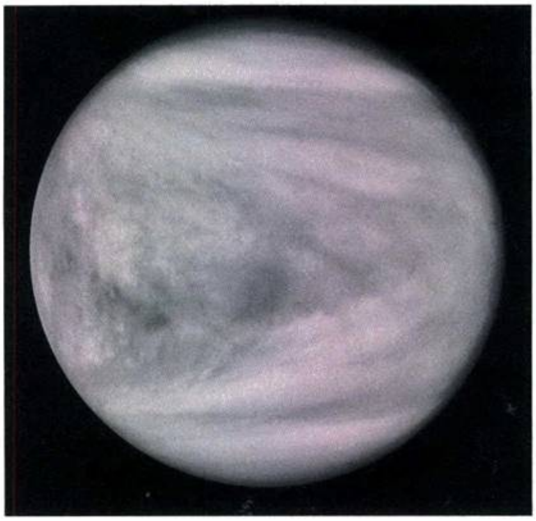
Galileo will study the entire Jovian system — its atmosphere, four main satellites, and magnetosphere — with an orbiter and an atmospheric probe. "*Galileo* is carrying a tremendously rich payload — eighteen instruments in all," said science and mission design manager William O'Neill, also at JPL. "Despite the delays the mission has experienced, these instruments represent state-of-the-art technology. The camera system is the best that's ever been flown." The mission's solid-state camera will produce images over one hundred times more sensitive than those from *Voyager*.

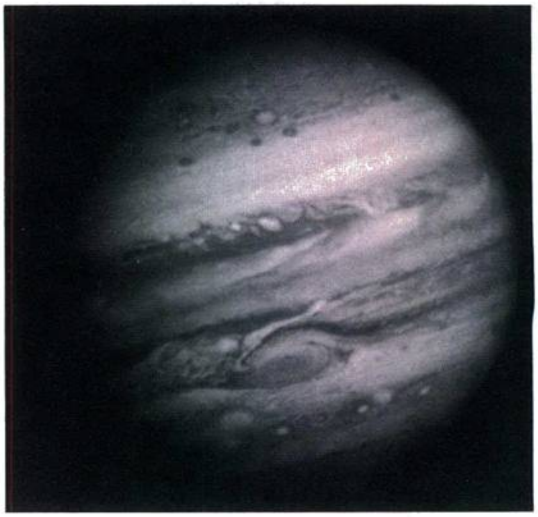
Although both missions will produce equally intensive studies of their respective planets, *Galileo* is the bigger mission of the two. The project has cost nearly $900 million to build, about twice the cost of *Magellan*. The innovative new design of the spacecraft, which allows one section of the craft to remain stable while the rest of the craft rotates, permits *Galileo* to carry many different types of instruments and investigate many diverse scientific areas.

Two Years at Jupiter

In its nearly two-year-long stay at Jupiter, *Galileo* will orbit the planet in ten different elliptical orbits, each time making a close flyby of one of the Galilean satellites. The gravitational influence of one satellite will be used to redirect the spacecraft's orbit and put it on a trajectory for another close satellite flyby on its next pass through the Jovian system.

Magellan, on the other hand, is a more focused and economical mission than *Galileo*. Many of the spacecraft's components are spares from other missions. The 12-foot-diameter dish antenna, which will perform double duty as both a radar antenna and a radio transmitter to Earth, is a *Voyager* spare, as are the twelve small thrusters; the main computer system was developed for *Galileo*. But the amount of information it will return to Earth will be truly astronomical — more





THE SWIRLING ATMOSPHERES of Venus (top) and Jupiter will be pierced by instruments carried aboard two new U.S. planetary spacecraft.

than the combined data return from previous United States planetary missions.

Once it gets to Venus, *Magellan* will collect and transmit data at a breakneck pace. Every 3 hours and 9 minutes it will orbit Venus as the planet slowly rotates through its 243-day cycle below. On each orbit the radar maps the surface for 37 minutes, quickly turns itself to point its antenna toward Earth, plays back part of the data stored on its tape recorders for 56 minutes, checks its position by fixing on a star, transmits another 56-minutes worth of data, turns again to point the antenna back at Venus, and begins another mapping run. *Magellan* must perform this drill with great accuracy over 1,800 times to complete one global surface map of Venus.

Since the first spacecraft flew by Venus in 1962 (*Mariner 2*), the United States and the Soviet Union have sent twenty spacecraft to the planet. The atmosphere has been studied by parachuted probes and balloons, the surface analyzed by Soviet landers, and the planet mapped by orbiters. But a complete and detailed global map has not yet been attained.

Better Map of Venus

The U.S. *Pioneer Venus* mission launched in 1978 mapped 93 percent of the surface but only to a resolution of sixty miles, accurate enough to show large-scale features like continent-size highland areas, mountain peaks, and hilly plains. The Soviet *Venera 15/16* orbiters improved the resolution in 1984 to one-and-a-half miles, but they only mapped 30 percent of the surface.

Magellan will see features only three hundred yards across. With that accuracy, scientists will be able to read the geologic history of Venus in great detail. Volcanic craters will be distinguished from impact craters. Individual lava flows will be resolved so the sequence of volcanic events that shaped the surface can be reconstructed. Any river deltas or marine terraces on the surface will stand out as evidence that water once flowed on Venus.

Such fine-scale mapping is only possible with precise spacecraft navigation and pointing of the radar antenna. "This mission is tremendously taxing on our capabilities," said Johnson. But because of this precision and the round-the-clock availability of NASA's Deep Space Network antennas on Earth to receive data from *Magellan*, the mission will be able to return more than one hundred times the amount of data that the Soviet *Venera* orbiters returned.

Jupiter has been visited by only four spacecraft — *Pioneer 10/11* and *Voyager 1/2* — and all were flyby missions that flew into and out of the Jovian system within a matter of days. *Galileo* will orbit Jupiter for twenty-two months as it studies the magnetosphere, analyzes the Jovian atmosphere, and makes repeated close flybys of the four Galilean moons. The closest any previous probe got to one of these moons was *Voyager 1*'s 13,000-mile flyby of Io. *Galileo* mission planners hope to fly closer than 1,000 miles from each of the satellites.

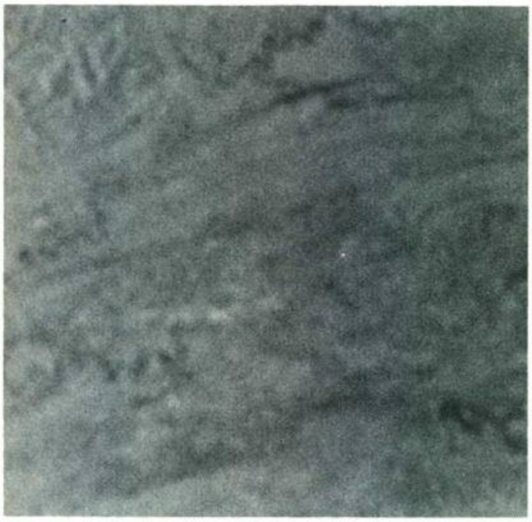
To get the first direct sampling of Jupiter's atmosphere, the little probe aboard *Galileo* will have to endure the fastest atmospheric entry of any manmade craft. The probe will hit the atmosphere at 100,000 miles per hour and will produce temperatures so hot they cannot be tested in a laboratory on Earth. The probe's cone-shaped heat shield, made of the same materials used for Earth re-entry vehicles, is thicker — more than five-and-a-half inches at its tip — than similar probes used at Venus.

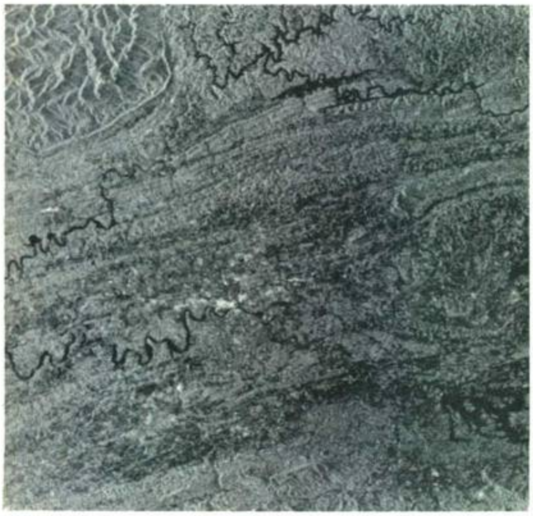
"Direct sampling of the atmosphere is a qualitatively different type of data than we have been able to get from remote-sensing instruments," said *Galileo* project scientist Torrence V. Johnson. The instruments contained in the probe will measure the temperature and pressure of the atmosphere, analyze the composition of atmospheric gases, and possibly even detect lightning.

Galileo and *Magellan* will make discoveries at Jupiter and Venus that will change the way we look at these planets and the solar system as a whole. These revolutionary discoveries, however, will be produced by evolutionary advances in technology. Neither mission's success depends on a single radically new capability but on a combination of established techniques and innovative advances.

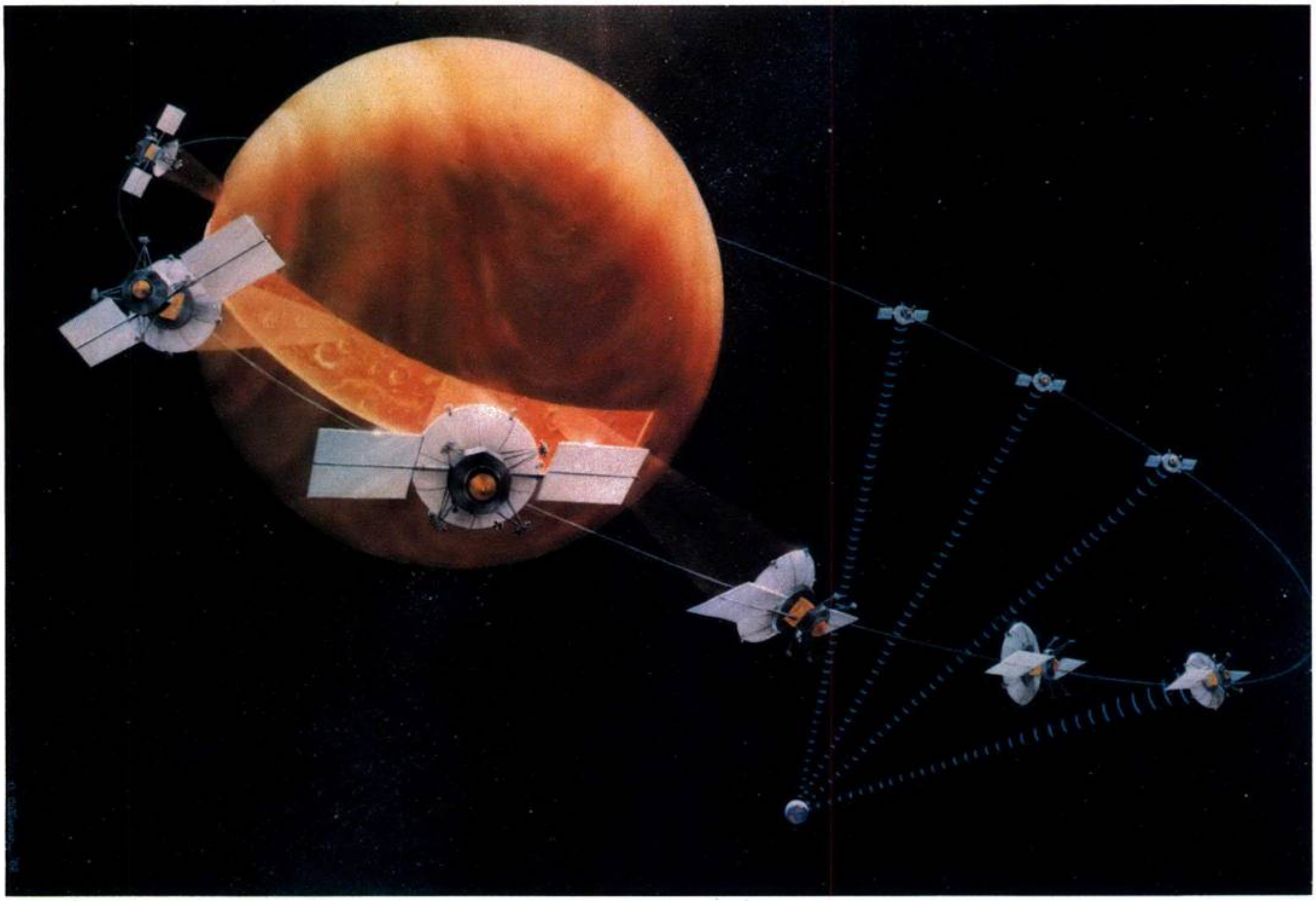
The secret of *Magellan*'s success is in principle very simple: make a small antenna act like a big antenna. Like a telescope's primary mirror, a radar's antenna collects "light," in the form of energy at radio wavelengths instead of optical, to produce an image. The larger the telescope mirror, the more light is collected and the better the image produced.

Unlike telescopes, the radar system is the source of the energy its antenna receives. A carefully measured microwave pulse is emitted by the radar at an object, in *Magellan*'s case the surface of Venus. When the pulse hits the object, assuming the object is not perfectly smooth, it scatters in many directions and the resulting echoes are changed by the characteristics of the





FINE-SCALE FEATURES on Venus will stand out vividly in *Magellan* radar images. This pair of images, derived from a terrestrial satellite photo, represents the improvement in resolution *Magellan* (bottom) will have compared to the Soviet *Venera* mission (top).



EVERY THREE HOURS *Magellan* will orbit Venus, first imaging the surface through the thick Venusian clouds, then sending its radar data back to Earth.

object it struck. When these echoes are collected, an image can be produced of the area originally illuminated by the radar pulse. The bigger the antenna, the more echoes collected and the better the resolution of the image.

Antenna Thinks Big

But there are practical limits to the size of an antenna, especially one that has to travel all the way to Venus. So *Magellan* planners borrowed a technique that has been used by the military for years: synthetic-aperture radar, or SAR. SAR has also been used for Earth-imaging missions such as the *SEASAT* oceanographic satellite and two space shuttle experiments. SAR images produced by the shuttle systems revealed Mayan agricultural canals beneath the Guatemalan rain forests and ancient river beds buried below the sands of the Sahara.

SAR duplicates the collecting power of a big antenna with a small one by sending many successive pulses at a given area, thereby producing multiple echoes from that area. These multiple sets of echoes are stored in computer memory and then combined in a herculean computer-processing effort to produce a single image that would match the resolution of a much larger antenna collecting echoes from a single pulse.

On each of its orbits around Venus, *Magellan*'s radar will image a swath of the surface 15 miles wide and 10,000 miles long. Because Venus rotates 12 miles at the equator between each of *Magellan*'s orbits, there will be some overlap between swaths. The radar makes 6,000 views of the surface in each swath, exposing every point within the swath at least four times.

Magellan stores this data — a total of 1.7 billion bits of information from each orbit — on its tape recorders and plays them back to Earth as fast as the antennas of the Deep Space Network can receive the data.

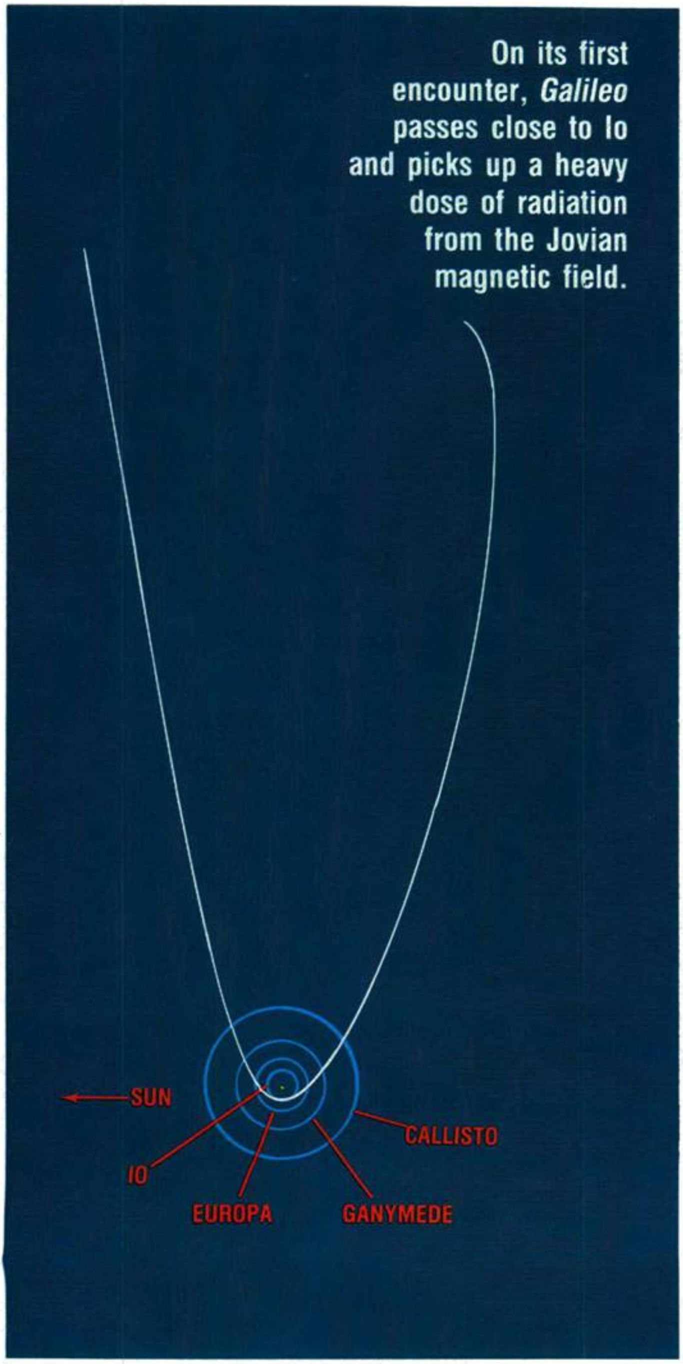
The *Magellan* radar operates in a burst mode, in which the transmitter sends a burst of pulses, turns off momentarily to receive the echoes from that burst, and then sends another burst. Bursts are sent as fast as five per second at the lowest altitudes of the spacecraft's orbit. Each burst is made up of hundreds of individual radio pulses sent one at a time in intervals measured in millionths of a second. The resulting echoes are received in the brief time between pulse transmissions.

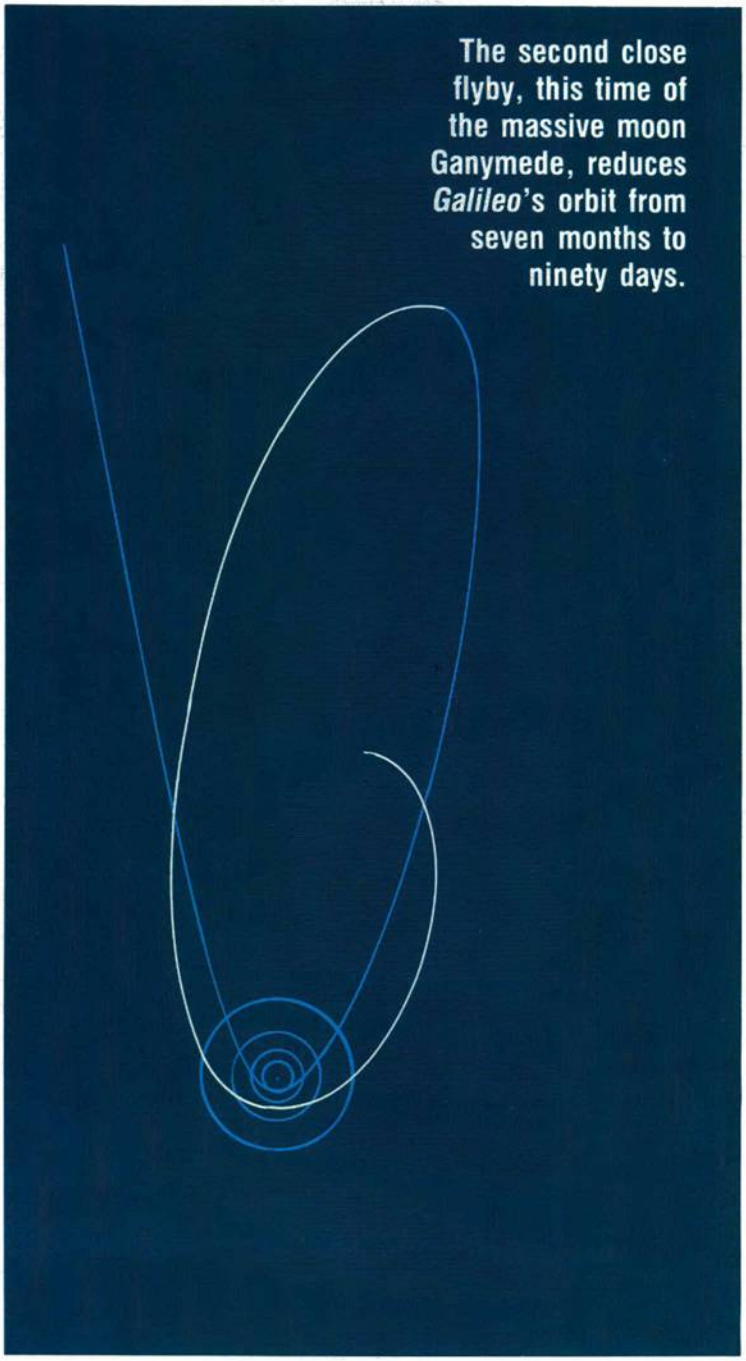
What the radar antenna receives is essentially noise — static — produced by millions of echoes returning from different points on the surface within the antenna's beam. The process of sorting out that noise begins on the spacecraft — where the noise is filtered, amplified, and digitized — and is completed in computers at JPL. The data-processing involved is so extensive that without the introduction of relatively inexpensive, specialized super computers, there would not have been enough computing time available on JPL computers to handle the job.

The purpose of all this processing is to find out where individual echoes came from on the Venusian surface. By sending the radar beam off to one side of the spacecraft's flight path instead of directly below it, the time it takes for echoes to travel to the surface and back varies. By measuring the travel time, the echo is placed somewhere along an arc equidistant from the spacecraft's position above the surface.

To find out exactly where along that arc an echo came from, another property of the echo — its change in pitch — is measured. Because the spacecraft is in motion as the pulse travels to the surface and the echo returns, the pitch of the returning signal is Doppler shifted a certain amount depending on how far in front of or behind the spacecraft the signal hit the surface. Echoes with the same Doppler shift

ORBITING JUPITER: A TRIAL RUN


On its first encounter, *Galileo* passes close to Io and picks up a heavy dose of radiation from the Jovian magnetic field.


The second close flyby, this time of the massive moon Ganymede, reduces *Galileo*'s orbit from seven months to ninety days.

define a line that intersects the spacecraft's flight path.

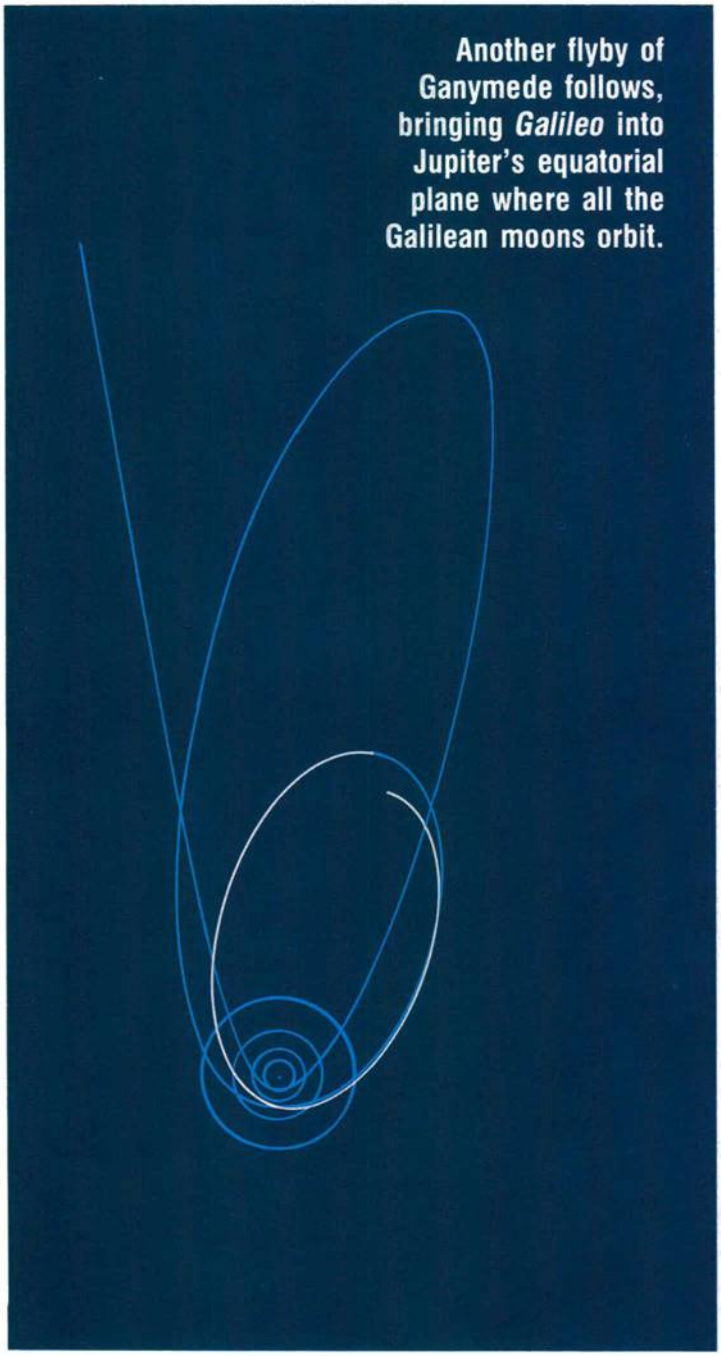
An echo originated from the point where the arc defined by its distance meets the line defined by its Doppler shift. Now that the echo is located, the strength or brightness of the echo, which varies according to the type of terrain it encountered, is positioned to become an element of the final image.

The data produced by each burst is processed into a single-look image of the surface. Overlapping images are then combined to produce a multiple-look image that has much less noise in it than any single-look image. The result will be more than 1,800 image strips that will be combined to form a global map of the planet.

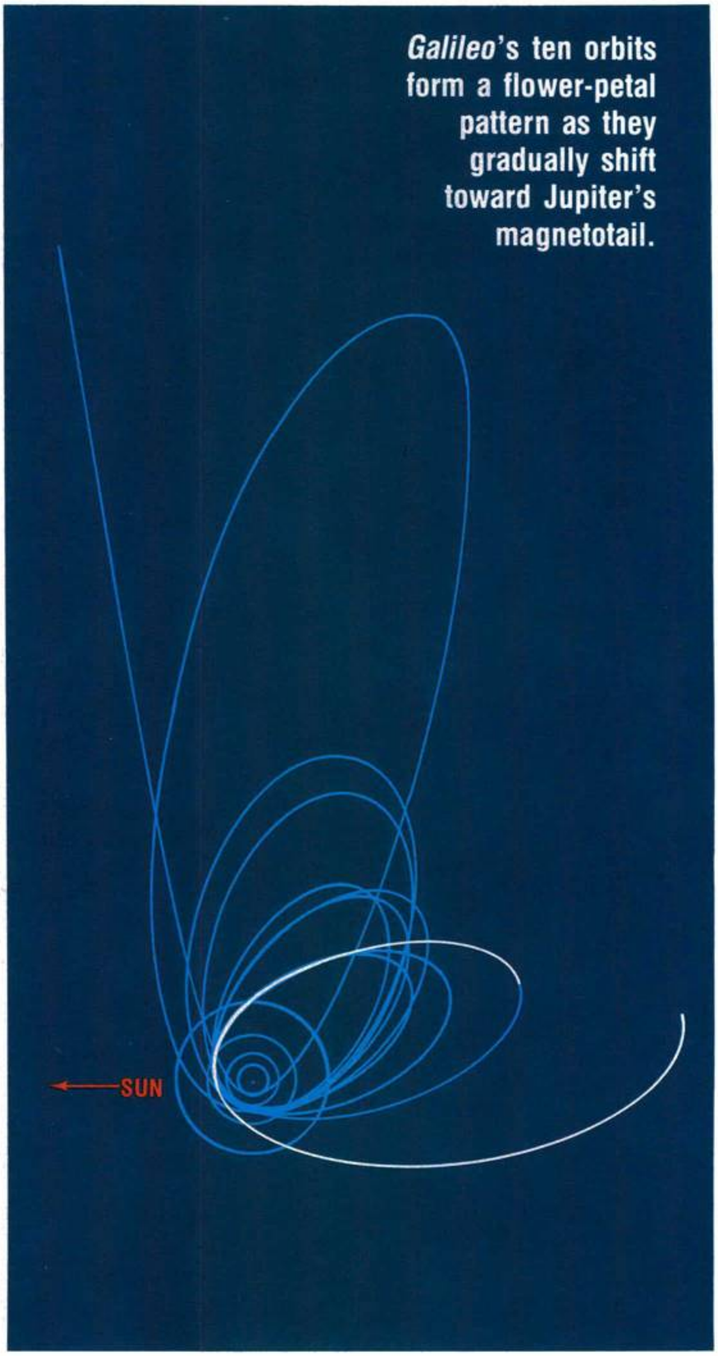
The revolutionary discoveries *Galileo* will make at Jupiter are guaranteed by the basic definition of the mission: to be the first probe to orbit one of the gas giants. *Galileo* will not follow the same type of strictly repetitive orbits *Magellan* will use to map Venus. Instead, each of *Galileo*'s ten orbits will be unique. Each will be designed to achieve different scientific objectives as well as to set up the next orbit.

Although the exact trajectories of these orbits have not yet been designed — and won't be until after

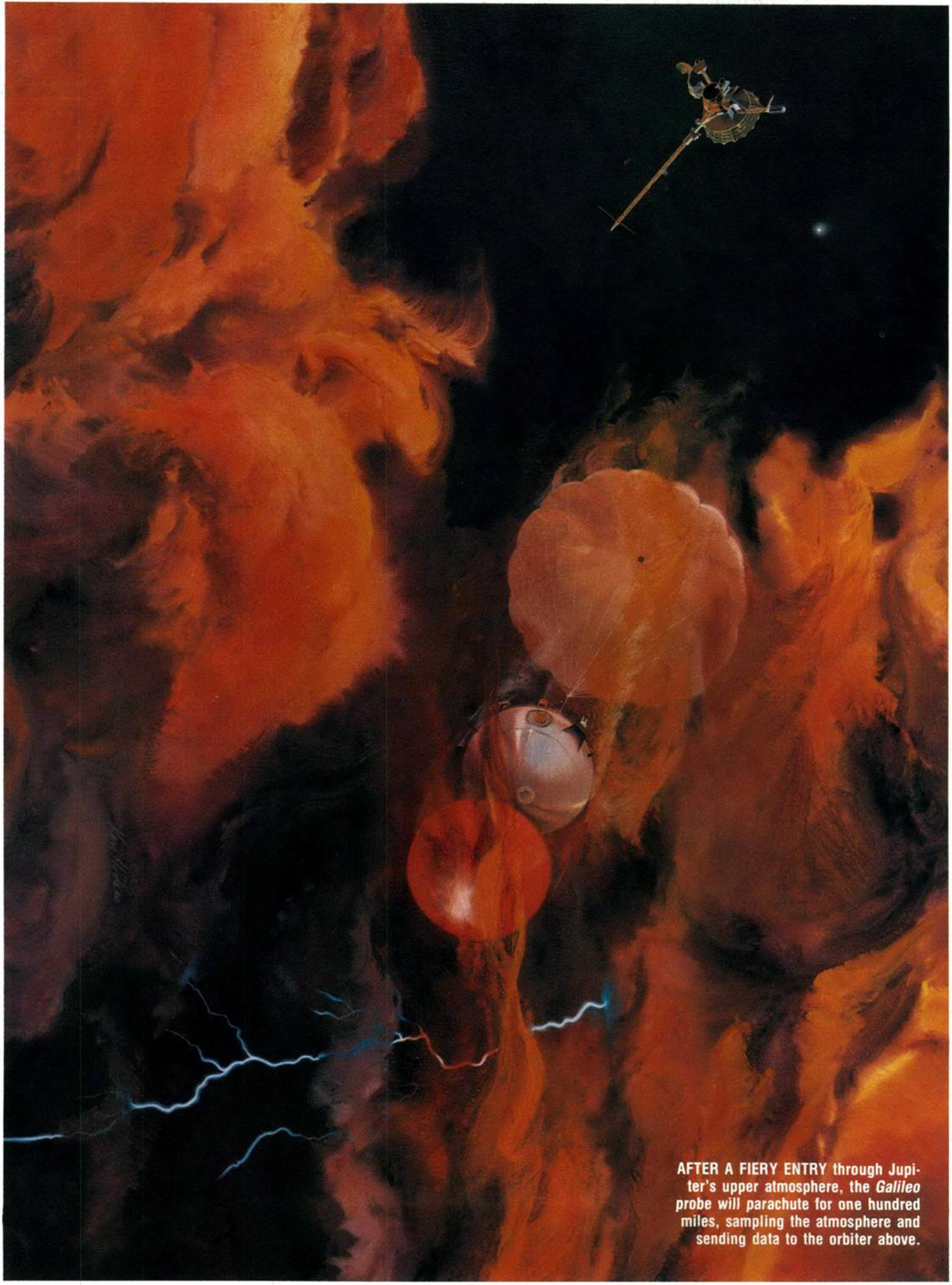
A CLOSE FLYBY of Jupiter's innermost Galilean moon Io will slow *Galileo* down and help put it in orbit around Jupiter.



Another flyby of Ganymede follows, bringing *Galileo* into Jupiter's equatorial plane where all the Galilean moons orbit.



Galileo's ten orbits form a flower-petal pattern as they gradually shift toward Jupiter's magnetotail.



AFTER A FIERY ENTRY through Jupiter's upper atmosphere, the *Galileo* probe will parachute for one hundred miles, sampling the atmosphere and sending data to the orbiter above.

Galileo has left Earth — the mission's science goals and the inescapable mandates of celestial mechanics have fixed certain parts of *Galileo*'s "grand tour" of Jupiter. The first major science requirement is getting the probe into the Jovian atmosphere and positioning the orbiter so it can receive the data from the probe and relay it back to Earth.

The probe is released by the orbiter five months before they both reach Jupiter. The 700-pound probe cannot be guided after this time, so the orbiter is carefully pointed to send the probe on the right path. When the probe is just six hours away from entry into the Jovian atmosphere, a timer "wakes up" the probe and operations begin.

In the two minutes after the probe hits the atmosphere, the heat shield does its job as the probe quickly decelerates over a distance of 250 miles. Explosive bolts fire to separate the rear cover from the heat shield. A parachute quickly unfolds and separates the probe from the heat shield. A few seconds later the probe's transmitter turns on and begins to beam data from its instruments to the orbiter overhead.

Sampling Jupiter

The probe parachutes through Jupiter's hydrogen and helium atmosphere, which at this point is less dense than the atmospheric pressure on Earth at sea level. For the next seventy minutes the orbiter listens as the probe falls another one hundred miles. By this time the atmospheric pressure has increased to twenty-five times that at sea level and the probe is destroyed.

Both the probe and the orbiter enter the Jovian system slightly out of the equatorial plane to avoid a collision with Jupiter's rings. But once the probe has successfully reached Jupiter, the orbiter needs to change its orbit and get into the equatorial plane because that is where all of the Galilean satellites are.

"We've got two jobs on our hands after we get to Jupiter," said mission design manager O'Neill, "getting into the equatorial plane and getting good orbits." The first orbit requires a close flyby of the innermost Galilean moon, Io, so the orbiter can slow down and get into orbit around Jupiter.

This initial pass will be the closest the orbiter will get to Jupiter during the entire mission, and it carries a heavy price. The energetic electrons and protons captured in Jupiter's radiation belts make such a close approach very hazardous. "The craft has been radiation-hardened, just like a weapons system," said O'Neill. "But even then that first pass exposes the orbiter to 50 percent of the radiation that we expect it can endure." After the first flyby the orbiter does not come inside the orbit of Europa.

After the Io flyby there will be a fixed sequence of satellite flybys: Ganymede, Ganymede, and Callisto. The Io flyby will send the orbiter into a 230-day-long elliptical orbit. With the first Ganymede flyby, the orbital period will be reduced to 90 days and perijove — the closest point in an orbit to Jupiter — will be raised safely beyond the radiation belts.

"With the second flyby of Ganymede we get out the inclination," said O'Neill. "After that, all we're changing is the period."

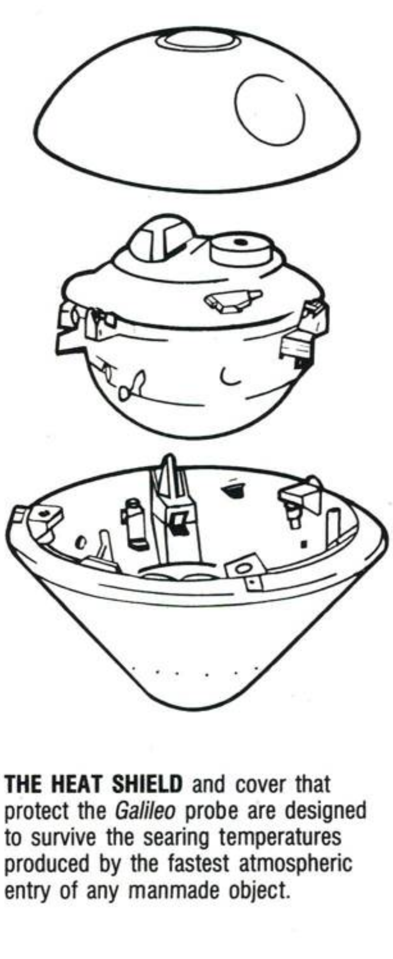
The mission's science objectives also shape the general pattern of orbits. Because one of the objectives is to sample Jupiter's magnetotail, the region that stretches far behind the planet opposite the Sun, mission designers must rotate the orbits toward that position so at least one orbit passes through the magnetotail.

If *Galileo* survives radiation exposure and its propellant lasts long enough, the orbiter will undertake additional orbits. A second close flyby of Io is one possible target, but because this would bring the craft back into the radiation belt, that would most likely be its last useful orbit.

Right now the success of both missions relies on one thing more than any other: the space shuttle. To make a planned rendezvous with the Moon or a planet, a spacecraft has to leave Earth within a tightly proscribed time frame, or launch window.

Magellan is scheduled to begin its journey on April 28 aboard the fourth shuttle flight and arrive at Venus in August 1990. If *Magellan* is not launched before May 23, it will have to wait twenty-five months, until May 1991, before it can try again. *Galileo* is currently scheduled as the seventh shuttle launch on October 13, and it has until November 24 to leave Earth so it can make its December 7, 1995, rendezvous with Jupiter.

Both missions are now in the final stages of preparation. *Magellan* is already at Kennedy Space Center undergoing final assembly and testing; *Galileo* will leave JPL for Kennedy in May. As the clock runs down on the launches of both missions, anticipation is increasing among mission personnel. There is speculation about how each mission could surpass its expected productive lifetime and return even more data than planned. In a matter of months the long drought in U.S. planetary exploration will be over and a new decade of discoveries will begin. □



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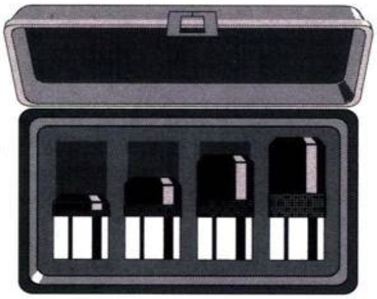

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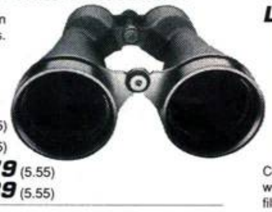

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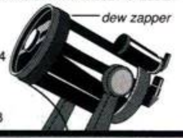

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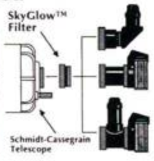

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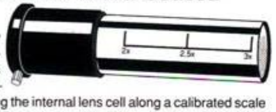

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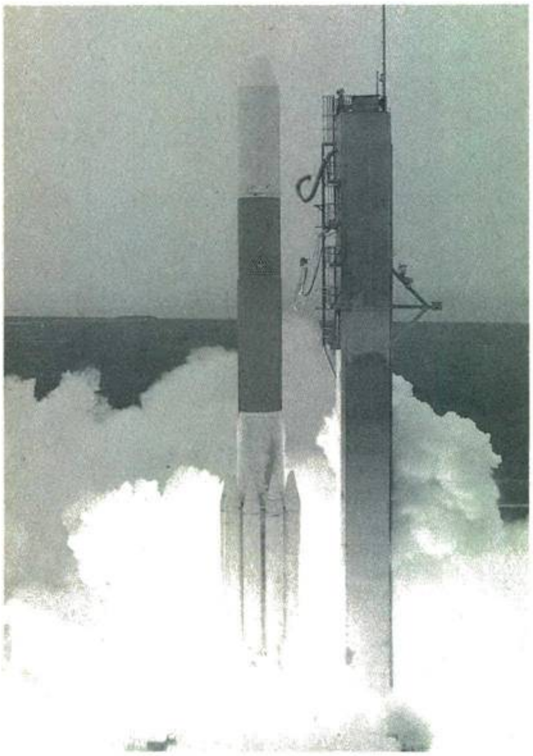
Launched by sounding rocket, balloon, and shuttle, small-scale missions complement the science performed by larger missions.

by Stephen P. Maran



EXPENDABLE ROCKETS now give astronomers an alternate way to get small space missions into orbit.

If you read newspapers or watch television, you might get the impression that "space astronomy" consists entirely of large-scale missions like the *Hubble Space Telescope* and the planetary missions *Magellan* and *Galileo*. But that is far from the truth. Many small and moderate-sized missions planned for the next few years promise important breakthroughs in our understanding of the universe.

These smaller payloads will reach space in a variety of ways: some aboard the space shuttle, some on expendable rockets, some on sounding rockets, and some via scientific balloons. What the missions have in common is a significantly lower cost than the large missions and a limited number of experiments that target specific astronomical questions rather than try to get a broad overview. Many of the missions are designed to fly more than once, so astronomers can analyze the data, decide what kind of follow-up observations are desirable, and then modify the equipment for later flights.

Small science missions also play a vital role in training and developing young scientists. Many of these missions are designed and built, and the results later analyzed, in small university laboratories. This offers students and researchers an invaluable opportunity to participate in the scientific process. An informal survey conducted this past fall found a number of these astronomers hard at work preparing for their upcoming missions.

Getting Ready for Launch

One of the next missions to fly will be the *Cosmic Background Explorer*, or *COBE* for short. *COBE* is expected to continue the tradition, established by over sixty *Explorer* satellites, of producing great scientific returns in the areas of astrophysics and near-Earth studies at only a moderate cost. *Explorer*-class missions today cost roughly $100 million, compared with price tags of several hundred million dollars to over $1 billion for projects the size of *Magellan*, *Galileo*, and the *Hubble Space Telescope*.

COBE is designed to make precise measurements of the so-called primeval background radiation — a relic of the Big Bang explosion that created our universe. (See "*COBE*'s Quest" by Claude J. Bauer, August 1986.) Astronomers believe this radiation is from the era, about 100,000 years after the Big Bang, when the hot, young universe became transparent to radiation as electrons combined with atomic nuclei to form the first atoms.

COBE will measure both the brightness of the background radiation in all directions and the radiation's intensity at different wavelengths. Recent results from an instrument on a Japanese sounding rocket, flown in collaboration with Berkeley astronomers, indicate that the spectrum of the background radiation departs significantly from that expected — that of a black body glowing at a temperature of 2.7 kelvins. The sensitive infrared and microwave instrumentation of *COBE* will determine if that indication is correct.

The satellite may also help astronomers discover what causes the departure. Is it due, for example, to radiation from an early generation of very massive stars, which may have preceded the formation of galaxies? Or is it due to a glow from hot dust in the early universe? If either of these possibilities is correct, then the change in the background radiation that makes the spectrum deviate from the predicted spectrum occurred after the moment of first transparency. On the other hand, the distorted background spectrum might have more fundamental cosmological importance: It might be the signature of an event that occurred before the universe cleared.

COBE is scheduled for launch this spring on "the last of the old Delta rockets," according to Michael Hauser, principal investigator for one of the three experiments on the craft. *COBE* was originally designed to be carried into space on a space shuttle launched from the Western Space and Missiles Center (WSMC) in California. Only from there could the shuttle place the satellite into a 560-mile-high polar orbit, which is required for its mission. However, in the wake of the *Challenger* accident, the Air Force put plans to operate a shuttle-launch facility at the WSMC on indefinite hold. A Delta rocket, which can be launched from the WSMC, has been chosen as the new launcher.

The *COBE* scientists and engineers are now in the last throes of their major reworking of the satellite. "We've redesigned, rebuilt, and retested *COBE* at Goddard Space Flight Center for the Delta launch," Hauser said, and the work is now being completed. A future launch vehicle, the Delta II, will be capable of carrying heavier payloads, but engineers lightened *COBE* enough so an existing Delta rocket could accommodate it. And they did this without any loss in the satellite's scientific capability, even though the weight of the spacecraft and instruments was pared from 10,500 pounds to just 5,000 pounds.

Weight wasn't the only factor in the new design: the Delta has a much smaller capacity than the shuttle's cargo bay, so the structure of the spacecraft had to be modified also. The communications antenna and the solar panels, for example, initially built as fixed structures protruding from the spacecraft, now fold up to fit inside the Delta rocket shroud. The sunshade, which helps keep the telescope cool and doubles as a shield against radio frequency interference, has been remade to unfold in orbit like an umbrella.

From Lab to Space

This past fall *COBE* project scientist John Mather and his team were busy assembling the spacecraft at Goddard. In October they began loading the spacecraft's large Dewar (a kind of thermos bottle) with liquid helium. The Dewar, developed by the Ball Aerospace Systems Group in Boulder, Colorado, is outwardly the same size as the one flown on the *Infrared Astronomical Satellite*, yet it holds 25 percent more liquid helium because the inner container of the bottle is larger. The mission's scientific goals require that the Dewar keep the sensitive *COBE* detectors cold (1.5 kelvins) for at least six months, but the project scientists hope it will last for as many as fourteen months.

One of the next *Explorer* missions after *COBE* will be the *Extreme Ultraviolet Explorer* satellite, or *EUVE*. Right now all the work on *EUVE* is in the lab. But the launch, scheduled for 1991 on a Delta II rocket, is fast approaching, and everything has to be ready by that time. Stuart Bowyer, who heads the science team for this project at the University of California, Berkeley, said, "At this stage of the game we're testing some flight hardware. Almost all the pieces are made. Mainly it's a job of putting them together and testing them."

EUVE's prime goal is to conduct an all-sky survey at extreme ultraviolet

ASTRONOMICAL BALLOONS can lift small payloads above 95 percent of Earth's atmosphere and return them safely for later use.

wavelengths — the virtually unexplored spectral region between about 80 and 900 angstroms. The *EUVE* survey is expected to catalog large numbers of hot objects: white dwarf stars, stars with bright coronae, and cataclysmic variable stars such as dwarf novae. By one estimate the survey will turn up ten times as many hot white dwarfs than are known currently. Extreme ultraviolet emissions from Jupiter and Saturn will be studied too, as will bright comets, should any appear. However, as in any first survey through a new window on the universe, the most interesting objects observed will undoubtedly be the ones no one is expecting. (See "The Extreme Ultraviolet: A Promising New Window on the Universe" by John K. Davies, July 1987.)

In a satellite project like *EUVE*, machinists and other shop specialists are just as important as optical and electronics experts. The *EUVE* telescope mirrors are made of metal, not glass, and they were "diamond-turned on a fancy lathe that makes a surface good to about a millionth of an inch," Bowyer reported. The lathe is at the University's Lawrence Livermore Laboratory. But that's not the end of the story: "After turning the mirrors, you have to rub out the little cuts caused by the diamond tool, yet avoid changing the figure of the mirror." This polishing was finished recently, and the mirrors for the telescope are now smooth enough that they should provide images more than sufficient for spectroscopy in the extreme ultraviolet.

SOUNDING ROCKETS are an inexpensive way to carry small payloads to the edge of space.

EUVE is the first *Explorer* mission to be flown with the Multi-Mission Modular Spacecraft — a platform that can be used by other *Explorer* missions. When *EUVE*'s 12- to 18-month science mission is completed, the space shuttle will retrieve the satellite, astronauts will exchange the *EUVE* payload with a new *Explorer* payload — the *X-Ray Timing Explorer* (*XTE*) — and then return *EUVE* to Earth. The modular design will allow astronomers to orbit a variety of missions at a lower cost than if each mission were totally independent.

A Long Wait at the Cape

Exchanging the *XTE* satellite for the *EUVE* satellite is just one example of the major role the shuttle will play in future small-science missions. Among other things, astronomers plan to use the shuttle's cargo bay as a base for making a host of astronomical observations at short wavelengths.

One such mission will be the Astro observatory. Astro is an attached payload, which means it operates in the cargo bay, then returns to Earth for calibration and any necessary repairs or upgrading before returning to space on a future flight to study new targets. The three original Astro instruments — the Hopkins Ultraviolet Telescope, the Ultraviolet Imaging Telescope, and the Wisconsin Ultraviolet Photopolarimetry Experiment — were designed for imaging, spectroscopy, photometry, and polarimetry at ultraviolet wavelengths. These instruments were delivered to the Kennedy Space Center in early 1985, ready for a March 1986 launch that would have enabled them to study Halley's Comet, among other targets. Then came the *Challenger* accident, and the

instruments went into storage. The delay in returning the shuttle to safe flight made it possibie to add a fourth instrument to Astro, the Broad Band X-Ray Telescope.

Astro is now scheduled for a March 1990 launch. The largest instrument on Astro is the Hopkins Ultraviolet Telescope (HUT), a 12-foot-long, 36-inch-diameter telescope designed to study ultraviolet radiation at wavelengths as short as 450 angstroms. Although HUT is much smaller than the *Hubble Space Telescope*, *HST* cannot study wavelengths much shorter than about 1,050 angstroms. HUT's observations of the far ultraviolet spectrum should provide important information on quasars, the intergalactic medium, and many other astrophysical phenomena.

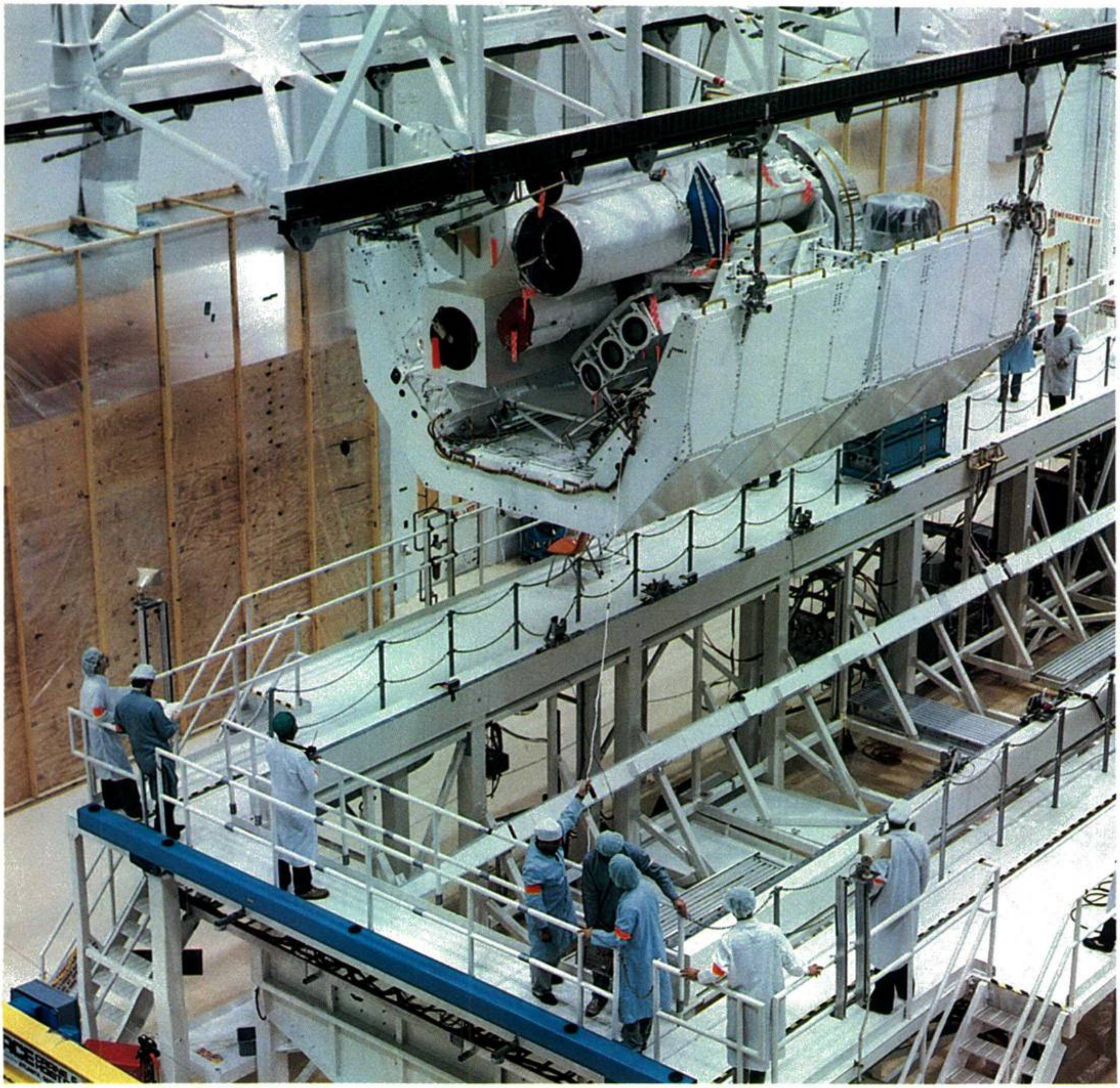
HUT and the other original instruments have been at the Cape so long that mission scientists decided to disassemble them to replace components that can deteriorate with time. Arthur Davidsen of Johns Hopkins University, the principal investigator for HUT, recalled recently that "we removed the whole spectrograph from the prime focus of HUT and took it to the laboratory to recalibrate it and test the aperture mechanism to see, if after years of being sealed, it would still

SMALL ASTRONOMICAL PAYLOADS launched by sounding rockets can be retrieved, modified, and flown again.

open and close on command as it is required to do on orbit." They found that the aperture mechanism worked, but the photocathode in HUT had degraded during the long delay and thus it is being replaced.

The second ultraviolet telescope on Astro is the Ultraviolet Imaging Telescope (UIT). This 15-inch-diameter telescope, developed at Goddard, is designed to take extremely sensitive photographs through a variety of ultraviolet filters. Principal investigator Theodore P. Stecher pointed out that although the UIT cannot match the superb spatial resolution of *HST*, it will be able to make photographs with a much wider field of view — 40 arcminutes versus 2.7 arcminutes for *HST* — and thus will be especially sensitive to extended objects like galaxies and nebulae.

The UIT is expected to target such objects as hot stars in globular clusters, the interstellar medium, and clusters of galaxies. One object the UIT team can observe now that it would have missed on a 1986 launch is supernova 1987A. A major goal of the astronomers is to study the light echo from 1987A and thereby make the first observation of the supernova's ultraviolet flash — an intense burst of ultraviolet light released when the



SOPHISTICATED yet relatively inexpensive, the three ultraviolet instruments of the Astro observatory are scheduled to fly on the shuttle in 1990.

supernova explosion broke through the dying star's surface.

The third original instrument is the Wisconsin Ultraviolet Photopolarimetry Experiment (WUPPE), which was developed by Arthur D. Code, Kenneth Nordsieck, and coworkers in the Space Astronomy Laboratory at the University of Wisconsin at Madison. WUPPE measures the polarization of ultraviolet light arriving from celestial sources. Polarization is a property of light waves when they vibrate preferentially in one plane or another as they travel through space. By determining the polarization of light from an astronomical object, you can learn about the structure and orientation of magnetic fields, dust clouds, and other phenomena in and around the light source. The Wisconsin astronomers expect WUPPE to provide new information on magnetic white dwarf stars, interstellar dust and reflection nebulae, and other objects.

During the launch delay the Wisconsin team has developed an advanced device for calibrating WUPPE's polarization measurements. According to Nordsieck, the new equipment enables the astronomers to repeat and improve on a rushed calibration that was done just before WUPPE was shipped to the Cape in 1985.

Besides improving WUPPE's calibration and installing better components in HUT, a new, fourth instrument will now enhance the ASTRO mission. The Broad Band X-Ray Telescope (BBXRT) has been added to Astro's payload to obtain spectra at x-ray wavelengths. The unique capability of this telescope is that it gathers a lot of x-rays. Peter Serlemitsos of Goddard Space Flight Center, who heads the BBXRT team, said BBXRT will collect roughly ten times the x-rays that the Einstein x-ray observatory could. The mirrors are not intended to form precise images but to act as "light buckets," Serlemitsos said, to gather x-rays for spectral analysis.

With this unprecedented spectral resolution, BBXRT will investigate the changing x-ray spectrum of supernova 1987A and study the x-ray spectra of many quasars and other sources that were simply too faint for detailed spectral analysis by earlier x-ray telescopes. In addition, BBXRT should reveal fine details in the x-ray spectrum of x-ray binary stars. By observing shifts in the spectral lines from these objects, astronomers may learn what is going on in the swirling streams of matter falling onto neutron stars and black holes.

Unlike the hours or even days that orbiting observatories can observe a single object, astronomical sounding rockets provide astronomers with exposure times measured in minutes. Nevertheless, sounding rockets offer some important advantages over larger launch vehicles. The relatively inexpensive sounding rockets are perfect for trying out new instrumental ideas: an astronomer can fly the instruments, recover the payload, and adjust or improve it as necessary for future flights. NASA currently launches about forty sounding rockets each year from locations around the world.

Rocketing into the Unknown

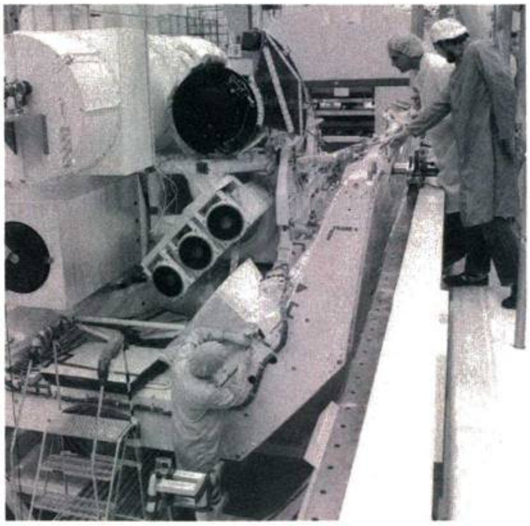
Princeton University astronomer Edward Jenkins is a major user of sounding rockets. Jenkins' payload is a very high resolution ultraviolet spectrograph that uses an echelle, which is a special kind of diffraction grating. It records just the short band of wavelengths from 1,000 to 1,150 angstroms, but it does so with unparalleled quality. In fact, Jenkins asserts that the spectrograph has recorded "the highest resolution spectrum ever obtained at wavelengths [too short to pass through Earth's atmosphere] for any object other than the Sun."

The 1,000- to 1,150-angstrom band is a very important wavelength range that the existing satellite observatory, the *International Ultraviolet Explorer*, doesn't cover. This far ultraviolet region "includes the important spectral lines of molecular hydrogen, deuterium, and oxygen VI [five-times-ionized oxygen]," Jenkins said, which are vital for studying the physical state of the interstellar gas. The payload has flown twice, most recently on September 11 from the White Sands Missile Range in New Mexico. Currently Jenkins is analyzing data from the September flight, when the rocket telescope pointed at Epsilon Persei, and he expects "to be flying this instrument once a year, hopefully including this spring."

A Trial Balloon

The quick turnaround and low-cost flights afforded by sounding rockets are also two of the advantages to launching astronomical payloads on balloons. And, as with the sounding-rocket program, the small scale of balloon missions means that students often get involved in the projects and thereby gain valuable experience.

Balloons, however, offer one distinct advantage that the shuttle, expendable rockets, and sounding rockets cannot: observing platforms at altitudes and for durations that are impractical or impossible with the other options. Balloons can carry payloads weighing as much as 5,500 pounds up to altitudes of 130,000 feet and can remain aloft for anywhere



NASA ENGINEERS TEST the Astro payload in a clean room facility at Kennedy Space Center.

from a few hours to several days.

Jonathan Grindlay of the Center for Astrophysics in Cambridge, Massachusetts, uses a balloon to lift his payload — EXITE or the Energetic X-Ray Imaging Telescope Experiment — above most of Earth's obscuring atmosphere. Last fall Grindlay was at the balloon base in Fort Sumner, New Mexico, where he was preparing his payload for an October launch. After the mission, his team will study the results and prepare the instrument for another launch in 1989.

EXITE is designed to make images of cosmic x-ray sources in the energy range from about 20 to about 300 keV (thousand electron volts), which correspond to wavelengths from about 1 to 1/25 angstroms. Grindlay said EXITE will "get us much greater sensitivity in its energy range than the first *High Energy Astronomical Observatory* satellite." Among the instrument's prime targets are black hole candidates. These objects emit copious amounts of x-rays, presumably as gas is heated to tremendous temperatures by friction in the regions surrounding the black hole. Grindlay also wants to aim the balloon telescope at a sample of quasars to determine the respective hard (meaning high-energy) x-ray spectra. This could answer a vexing question about the celestial hard x-ray background radiation — a diffuse glow that seems to come from all directions in the universe. Astronomers disagree about whether this background is due to vast numbers of quasars and other active galactic nuclei so far away that they cannot be individually resolved with present instruments. And Grindlay hopes he has the opportunity to take the telescope to Australia in 1989 to study the changing x-ray emissions from supernova 1987A.

SMALL RESEARCH TEAMS play important roles in smaller space missions. Here *Extreme Ultraviolet Explorer* project engineer Henry Heetderks examines a mounting structure in the lab.

A group of Harvard undergraduate students helped assemble one of the key components of the balloon telescope. EXITE resembles a large pinhole camera that has a great many pinholes instead of just one. Because most celestial objects emit very few hard x-rays, the pinholes are large squares — 12 millimeters or about half an inch on a side. The bigger the holes, the more x-rays get through.

The students were involved with the occulting cells, the solid square spacers between the open pinholes. The occulting cells must block x-rays so the x-rays pass only through the pinholes. To do that, three materials have to be combined in a laminate with layers arranged in the correct order.

Lead is the main x-ray absorber. However, when lead blocks high-energy celestial radiation, it produces x-rays itself, at an energy near 80 keV. To overcome this, the students had to place a layer of tin behind each square of lead. The tin blocks the 80-keV x-rays shining from the lead quite well, but the tin is stimulated by the 80 keV photons and produces x-ray emission at a lower energy. That energy, in turn, is blocked by a layer of copper, which completes the occulting cell. The students epoxied the three layers in each occulting cell together, then laid the cells out on a roughly 2-foot-square frame, sandwiched together between two panes of Lexan plastic. The frame then took its place in the payload.

The result is a telescope with a spatial resolution of about 10 arcminutes, a major advance for high-energy x-ray imaging. This enables the researchers to make reliable measurements of weak sources by simultaneously observing the x-ray source of interest and the adjacent x-ray background. The x-ray background consists of both a real component — x-rays coming from space — and an instrumental component, caused by cosmic-ray particles striking the detector. Even the strongest x-ray sources in the sky are just a few times stronger than the background, so to study weak sources, which are superimposed on a background stronger than they are, the astronomers have to measure both source and background with high accuracy.

A Busy and Bright Future

The missions mentioned above are just the tip of the iceberg: small and moderate-sized missions are now or soon will be observing a whole range of objects at many different wavelengths, tackling tough questions about our universe. Although they may lack the pizzazz of the large missions, they don't have the high price tag. Because many of the missions will fly frequently, innovation should be fostered as astronomers continually modify their equipment to get more out of it. And many small missions are products of small research teams on which the next generation of astronomers get the training they need.

As access to space increases in the wake of September's successful *Discovery* mission, the smaller space missions will take their place alongside the Great Observatories and the major planetary missions at the forefront of astronomical research. It appears that the current era of space astronomy can only get better. ☐

Stephen P. Maran is senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center.

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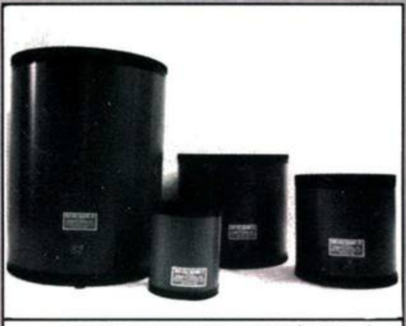

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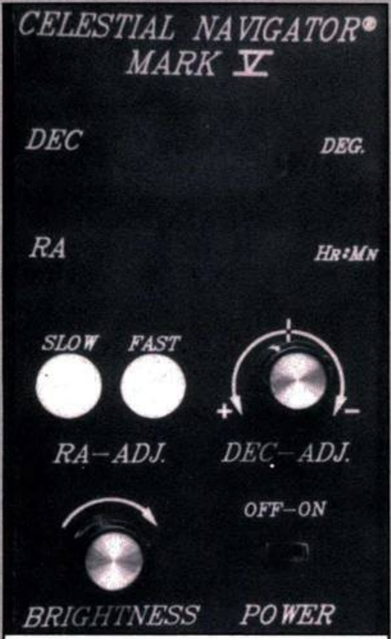

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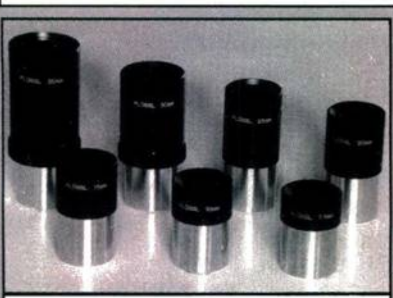

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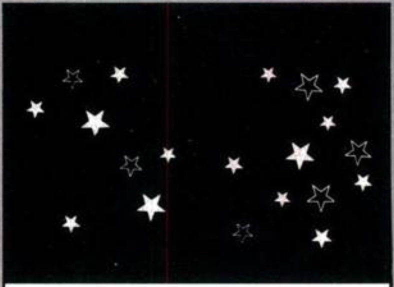

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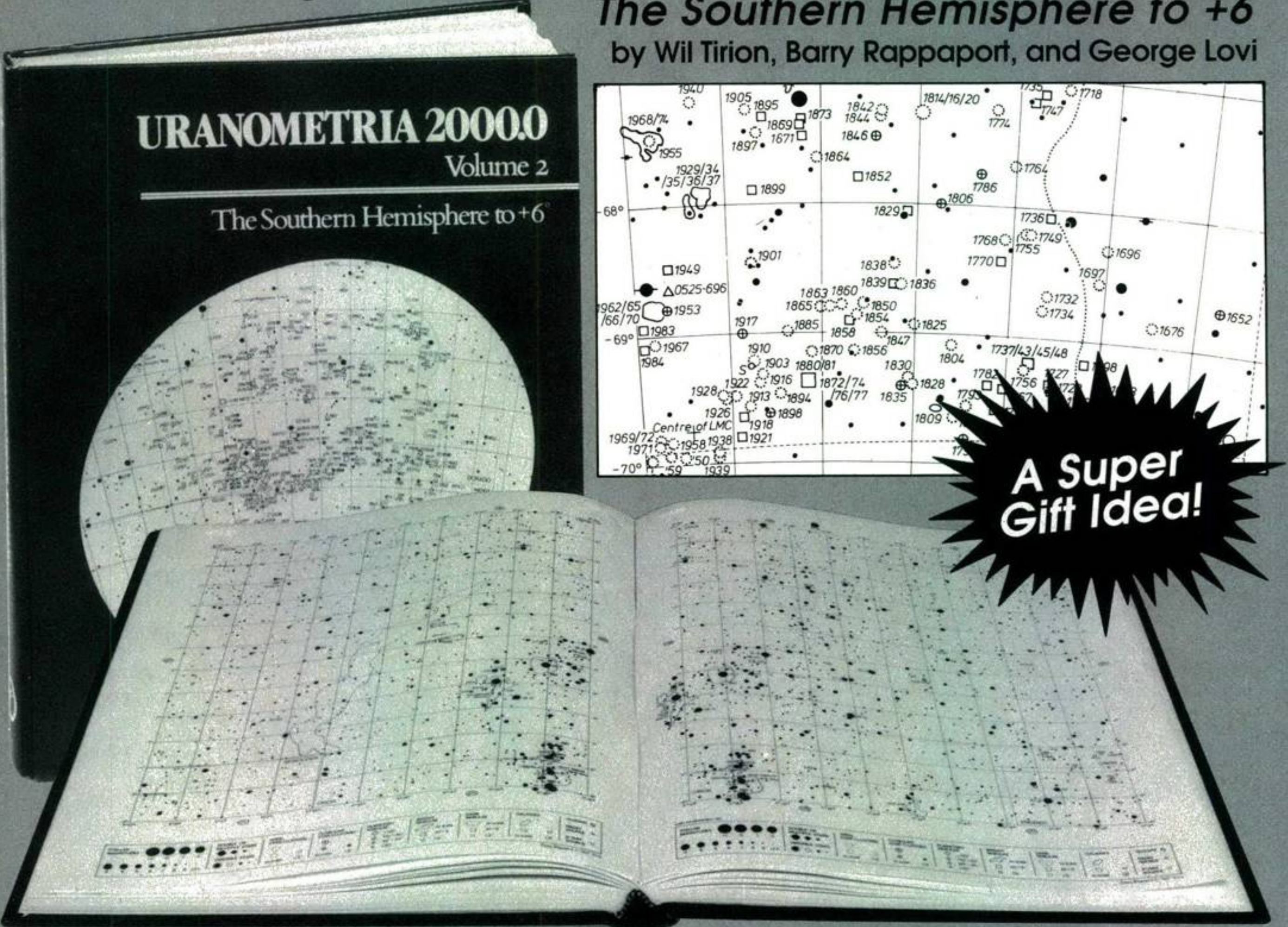
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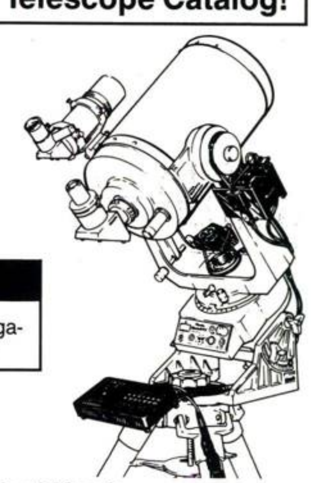

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THE PROMISE OF THE 21ST CENTURY

A National Academy of Sciences report recommends space science goals that will lead us to answers about the origins of life and of the universe.

Adapted from *Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015* (National Academy Press, 1988).

Early in 1984, NASA asked the Space Science Board of the National Research Council to undertake a study to determine the principal scientific issues that the disciplines of space science would face during the period from about 1995 to 2015. To carry out the study, the board put together six task groups on each space science discipline, including planetary/lunar exploration and astronomy and astrophysics.

The task groups were encouraged to be imaginative in considering new directions for their disciplines. The intent was to challenge the participants to expand their horizons and to garner as many stimulating ideas as possible for future enterprises in space science.

We recommend the task group reports to the reader for an understanding of the challenges that confront the space sciences and the insights they promise for the next century.

— Thomas M. Donahue, Chairman, Space Science Board

PLANETARY AND LUNAR EXPLORATION

Among the mysteries that have occupied human thought throughout history are the mechanisms by which the solar system came into existence, the laws and physical processes that shape the evolution and behavior of planets, and the relationship of the solar system to the wider cosmos. These questions continue to stimulate modern planetary science.

Planetary studies have additional significance from a human perspective. Planets are likely to be the only bodies in the universe capable of supporting advanced life. Among its other objectives, planetary science seeks to understand the formation of life-supporting planets and the conditions under which life arises and develops. The answers to these questions promise to help shape human perceptions about our origins and about our place in the universe.

To Understand the Origin of the Solar System

Serious attempts to devise a theory for the origin of the solar system go back more than three centuries. During the last decade a qualitative change has developed in our approach to this problem. This has largely been stimulated by the great wealth of information returned from lunar and planetary missions, by astronomical observations of young stellar objects, and from laboratory investigations of extraterrestrial material. What once was a field of science populated by a few lonely thinkers defending complete but idiosyncratic theories of solar system origin is now a field characterized by a healthy interplay among theory, observation, and experiment.

In association with this change, there has been significant evolution in thinking concerning the origin of the solar system. The picture that is emerging is one in which formation of disks of dust and gas is an essential component of the star formation process. Whether stars form out of such disks or whether the stars are the principal source of the disks is not yet clear. It is now generally accepted that these disks provide the birthsite for planetary companions to stars. But at present we are far from achieving anything that might be called a definitive understanding of this evolution of a gas-dust disk into a planetary system.

Because the formation of our planetary system is thought to have been a natural consequence of the Sun's formation, without the intervention of special circumstances, and because the formation of our Sun is thought to have involved processes typical of star formation in general, planetary systems are believed to occur commonly in the universe, although none has yet been detected. Indeed, our present ideas lead so immediately to the conclusion that planetary systems occur frequently around stars that failure to find such systems would force a fundamental revision of our theories about the origin of our planetary system and about star formation.

There are four major questions associated with the search for and study of other planetary systems. The first concerns the possible uniqueness of our solar system. This can be answered by detection of at least one other planetary system. As exciting as the confirmed discovery of another planetary system would be, the major scientific advances of such a discovery will lie in answering the remaining questions in this area of study. Second, we must seek to characterize planetary systems on a statistical basis. What is the frequency of occurrence of planetary systems as a function of spectral type of their central star? What are the masses of the planetary bodies relative to that of their central star?

The third major question concerns the detailed nature of specific planetary systems. This type of effort must involve a longer time base as it requires precise determinations of planetary masses and orbits and as much information on composition as possible. The fourth question concerns the cool material around stars in various stages of evolution. A central aspect of most modern theories on the formation of the solar system is the postulation of an accretion disk that evolves in such a way that it produces a central condensation (a star) and a suite of companions (planets). Identification and study of this circumstellar material will help place the formation of planetary systems in the broader context of the problem of star formation.

Research aimed at understanding the origin of the solar system focuses on those objects thought to retain clues about the primordial conditions and processes that contributed to the system's formation. Although critical information is obtained from measurements made of the evolved planets, the most detailed clues come from investigations of those small primitive objects that have changed little since the time of formation in the protoplanetary nebula: comets, asteroids, and certain meteorites.

The cold, volatile-rich matter of comets is thought to contain the most faithfully preserved samples of condensed protoplanetary material remaining in the solar system. The asteroids form an ordered assemblage of protoplanetary fragments, which seem to remain near the original locations of their formation. The compositional and structural variations of objects in the asteroid belt are thought to reflect the radial variation of conditions in the protoplanetary nebula.

We are far from achieving a definitive understanding of the evolution of a gas-dust disk into a planetary system.

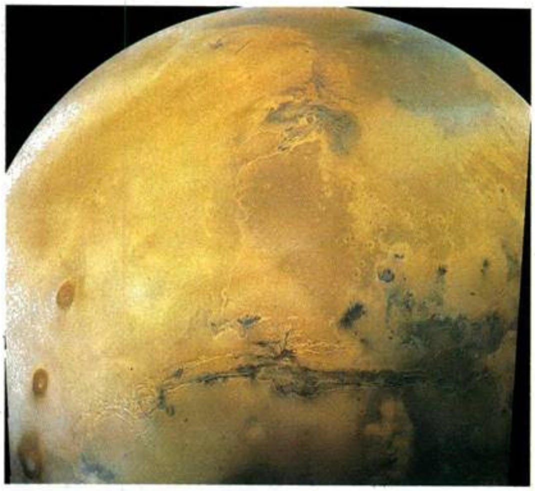
To Understand the Evolution of the Planets

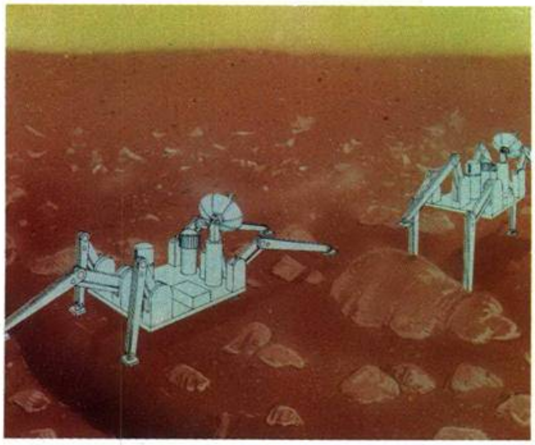
Research aimed at understanding the evolution of the planets and the physical processes that govern their behavior and their environments concentrates on those bodies that exhibit most clearly the consequences of planetary evolution. Because we live on Earth, a terrestrial planet, the evolution and environment of terrestrial planets are of special interest. Substantial advances in understanding can be realized by investigating, as a class, the terrestrial planets.

The major targets of comparative terrestrial planet research beyond Earth are Mercury, Venus, Mars, and the Moon. In addition, studies of many of the outer-planet satellites and of the largest asteroids are expected to reveal important information about solid planet evolution.

Several ongoing and planned missions in the planetary program are directed toward the study of terrestrial planets. However, a number of considerations suggest that it may be appropriate to undertake a special focus on terrestrial planet science within the context of an overall balanced program with Mars as the center of that focus.

Spacecraft investigations of Mars during the past fifteen years reveal that that planet has undergone perplexing changes throughout its history. Although today the planet appears dry and cold, there is clear evidence of an abundant flow of water several times in the past. Changes in the Martian surface environment directly pertain to concerns about the behavior of Earth's environment. It is evident that detailed study of the Martian crust will yield information about the character of the planet's past environments and perhaps clues regarding the influences that produced such marked environmental change. These studies may even help us to understand the Earth's ice ages.





The major mission recommended for the first decade of the study period is a Mars rover and sample-return program.

To Learn What Conditions Lead to the Origin of Life

Our search to understand the origin of life involves several planetary questions. It is important to know the physical conditions and chemical composition under which biological activity arose. It is also important to ascertain whether life forms have arisen elsewhere where they can be studied.

Presumably life arose out of an organic, prebiotic medium and was preceded by an interval of chemical evolution, which led more or less continuously into biological evolution. By understanding the formation of the planets, we will gain knowledge of the circumstances under which life arose on Earth. Many objects in the solar system seem not to have undergone substantial evolution since their formation. Some — Saturn's moon Titan, for example — are expected to carry important clues about the early material in which biological activity arose.

Investigations of the composition of cosmic matter and primitive solar system matter show that the basic building blocks of terrestrial life, including amino acids, occur naturally — at least in trace amounts. One of the most significant challenges in understanding the origin and distribution of life is to determine the extent to which special terrestrial conditions were involved in prebiotic chemical evolution. Detailed chemical assays of comets, asteroids, and other primitive objects will reveal the extent to which life could have arisen directly from preplanetary matter without an interval of special processing to condition the chemical mix.

To Learn How Physical Laws Work in Large Systems

Various phenomena result uniquely from the large scale of natural systems or from the long time scales over which slow processes work. Because these phenomena do not occur under normal laboratory conditions, it is only through direct observations in the solar system that we can expect to understand such important processes as planetary tectonism and volcanism and cosmic plasma processes.

In situ studies of physical processes occurring in the solar system strengthen our overall understanding of the behavior of natural systems. Our ideas about observable phenomena throughout the universe are shaped by detailed solar system investigations. Investigations of large-scale physical processes encompass virtually all of the objects in the solar system. The giant planets provide clues about properties of matter under high pressures, planetary interiors and magnetospheres demonstrate the curious behaviors of magnetized fluids and plasmas, and planetary atmospheres and surfaces present puzzles about long-term evolution of the complex interacting systems that constitute planetary environments and interiors.

Recommendations

Altogether, progress toward realizing these goals requires a balanced program of science and exploration. As the first level of investigation, reconnaissance by flyby missions attempts to reveal the major characteristics of a planet, such as its radius, mass, rotation rate, and the existence of magnetic fields, an atmosphere, oceans, satellites, and the like. The exploration phase follows and has the goal of describing and understanding the state of a planet and the general processes that have influenced its environment. This phase is carried out by long-lived orbiters equipped with a variety of cameras and other remote-sensing instruments.

The intensive phase of investigation addresses the highest-order questions revealed by the earlier phases. Detailed study of the properties of surface materials, interaction of surface and atmosphere, and biologic questions requires in situ measurements by soft-landed automated laboratories, mobile laboratories (rovers), and networks of instruments.

"Network science" is defined as geophysical measurements made over a relatively long time at several locations over a planet's or satellite's surface. Ideally a system would include an array of six to twelve stations with instruments to measure seismic events, physical properties of the surface, and heat flow. Networks of seismometers on a global scale yield information about the properties of the core, mantle, and lithosphere. Network stations can be emplaced by penetrators, semi-hard or soft landers, or a rover.

During the early part of the study period the task group recommends that *Galileo*-like missions explore the Saturn, Uranus, and Neptune systems. These spacecraft, with an extensive array of remote-sensing instruments, would carry out repeated flybys to characterize the major satellites.

Our own Moon remains a body of the highest scientific importance. The task group recommends that the proposed global survey by the *Lunar Geoscience Orbiter* be followed by deployment of rovers and a geophysical network, as well as resumption of sample returns.

The major mission recommended for the initial decade of the study period is a Mars rover and sample-return program consisting of linked missions launched in 1996 to 1998. Although autonomous robot vehicles may perform many of the initial exploratory activities, the later, more comprehensive exploration will require capabilities that now are possessed only by humans.

The cold, volatile-rich matter of comets is thought to contain the most faithfully preserved samples of condensed protoplanetary material remaining in the solar system.

ASTRONOMY AND ASTROPHYSICS

The past sixty years have brought about revolutionary changes in our understanding of the universe. For the first time we have been able to measure its size and age, to look back toward its birth in the very distant past, and to understand its present appearance and past evolution in terms of the laws of physics and chemistry discovered on Earth. We have found that our improved theoretical understanding of elementary particles, the fundamental constituents of matter, allows us to ask deep questions about the nature of the universe that we could not even formulate a short time ago.

To understand how the universe today evolved from its initial state, we must look back to the earliest times. In part, we can do this by using powerful telescopes that look far out into the universe. Optical and infrared observatories in space will look back in time to the era when the galaxies first formed. They will be able to analyze, with their powerful spectrometers, what the chemical constituents of the universe were at that time — whether hydrogen and helium were the only constituents present or whether some lithium and deuterium also existed. Measuring the abundances of these rare substances at those early times would provide us with a sensitive determination of the density of ordinary matter in the universe at the time when helium nuclei were formed. By inference it would also determine the nuclear matter density in the universe today.

Even though the details of astronomical knowledge change as new discoveries are made, there are three major themes that have guided the astronomers' quest for knowledge for several decades. These are to understand the origin of the universe, the laws of physics governing the universe, and the birth of stars and planets and the advent of life.

The Early Universe and Unidentified Matter

"Big Bang" cosmology — the theory espousing the explosive origin of the universe — met a crucial experimental test with the 1965 discovery of the cosmic background radiation. That measurement yielded a ratio of photons to protons in the universe and permitted calculation of the abundances of light elements produced in the first few minutes after the Big Bang. Studies of these abundances have since led to the conclusion that the density of normal nuclear matter in the universe is less than 10 percent of that expected of a closed universe, in fair agreement with dynamical constraints on the total amount of the universe's mass.

This implies that 90 percent of the mass of the universe is in unidentified form. It could take the form of massive neutrinos or even more exotic new particles like photinos or axions. This would have important implications for the origin of galaxies, which must have formed in the gravitational collapse of density perturbations in the cosmically expanding matter. As the universe evolved, most of the "normal" matter has, theoretically, been compressed by gravitation to form the stars and galaxies that we observe; these processes would be profoundly influenced by the presence of the greater bulk of matter in unidentified form.

Astronomers began to realize some years ago that there is some unidentified form of mass present in the universe. Galaxies have since been shown to be embedded in giant haloes composed of material whose presence can be inferred from its gravitational effects but that has not yet been detected directly at radio, infrared, optical, or x-ray wavelengths. The matter in such haloes appears to make up 5 or 10 percent of the critical cosmic density, but the data are not accurate enough to decide whether this unidentified mass could be in the form of very faint stars or whether additional matter of novel form is required.

Theorists are currently developing computer simulations of galaxy formation in a universe dominated by various types of unidentified matter. Such models have already demonstrated that if the unidentified matter is composed of massive neutrinos, then the large-scale structures such as clusters and superclusters should be more highly developed than galaxies themselves are observed to be. Hence, current attention is focused upon other particles that are more exotic than neutrinos. By 1995 it is expected that theoretical models of galaxy formation will be well developed, and it will be possible to compare observations of distant matter in the remote past with the predictions of particle physics.

Supernova eruptions are important in the evolution of our Galaxy because they are the principal source of turbulence and heat in the interstellar medium.

The Physics and Collapse of Strong Fields

The discovery of radio pulsars, neutron stars, and candidate black holes in x-ray binary stellar systems demonstrated that some stars collapse beyond the density of atomic nuclei. Theoretical models indicate that the collapse occurs within a fraction of a second when the core of a star becomes unstable; the bounce of an imploding stellar envelope off the just-formed neutron-star core is sufficient to eject the stellar envelope explosively in a supernova eruption. Such events are important in the evolution of our Galaxy because they are the principal source of turbulence and heat in the interstellar medium. They account for the acceleration of cosmic rays and create the heavy elements that later become incorporated into stars and planets like those of our solar system.

Some collapsing cores do not stop at the neutron-star stage but plunge on toward a black hole singularity. Astronomers have identified several objects believed to be stellar black holes in orbit around a normal stellar companion. With the aid of computer simulations, theorists are now studying the accretion process near rotating black holes. They are finding that these relativistic flows exhibit novel features that could help us to understand time variability in the emission from black hole candidates. We anticipate that more sophisticated theoretical models will yield new insight that may tell us whether individual sources are, in fact, black holes.

Gamma radiation is a tracer for highly relativistic particles — cosmic rays — both in the Galaxy and beyond. In our Galaxy the gamma rays emanate from a number of discrete sources, such as the Crab and Vela pulsars, but they also emanate from dense molecular clouds. This diffuse gamma-ray flux indicates the presence of highly energetic particles that interact with matter in these clouds. In ways we do not yet understand, this flux could reflect mechanisms that play a significant role in the formation of stars. It could, for example, indicate destruction of magnetic fields that have to be eliminated in order for protostellar matter to collapse to form stars.

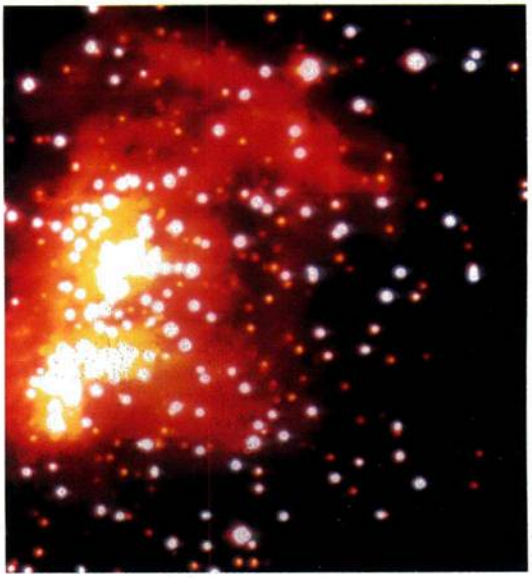
The mystery of the origin of cosmic rays is only partially solved at present. Acceleration of particles to relativistic energies occurs at a variety of scales: in the solar system in solar flares and planetary magnetospheres and in the Galaxy probably in stellar winds and supernova-driven shock fronts. Recent observations have indicated that binary x-ray sources containing compact objects such as Cygnus X-3 appear to be powerful particle accelerators at extremely high energies. We also know through observations of secondary photons in the radio and sometimes in the gamma-ray region that powerful particle acceleration must occur in almost all classes of extragalactic objects.

The Formation of Stars, Planets, and Life

Our own solar system was formed 4.6 billion years ago, probably through the gravitational contraction of a fragment of an interstellar molecular cloud. With radio and infrared telescopes we have the opportunity to observe similar processes at work today. Large numbers of active regions in molecular clouds appear to be candidates for star formation. Clouds of small particles have been discovered around several bright stars. These could conceivably represent a stage in the process of planet formation. Astronomers are already studying such events but need higher spectral and angular resolution to sort out the complex gas dynamics.

Planetary systems may well be a common phenomenon around stars like the Sun — roughly fifty of which lie within 10 parsecs from Earth. Whether the phenomenon of life is unique, rare, or a common occurrence appears now to be a problem that can be approached in a preliminary way. Instruments specifically designed for this purpose could carry out spectrophotometric analyses of the chemical composition of the planetary atmospheres.

For our own Earth the oxygen concentration in the atmosphere is far higher than one would expect if it were near chemical equilibrium. A similarly high oxygen concentration, if found in the atmosphere of another planet, would be highly suggestive of the presence of biological activity there as well. Our knowledge of how planets form and how life arises is slight, and surprises would surely result from such a program of exploration.



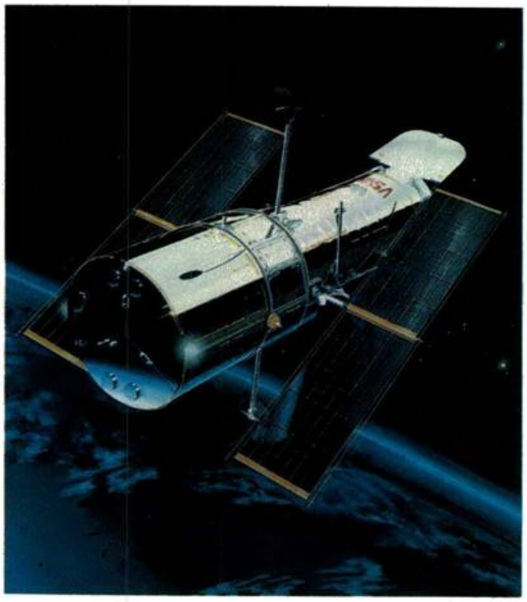
Although radio and infrared telescopes have revealed many regions of star formation, higher-resolution instruments will be needed to sort out the complex gas dynamics.

Recommendations

Experience shows that we have been most successful in explaining complex cosmic phenomena when we can observe across the entire wavelength range. Only in that way can a variety of different processes underlying a given phenomenon be distinguished from one another. Each process typically has distinctive signatures at different wavelengths: when we observe the Milky Way at optical wavelengths, we see a steady stream of light from stars. Infrared telescopes sense the heat emitted by interstellar dust and permit us to trace the distribution of dust clouds throughout our Galaxy. X-ray telescopes, in contrast, register x-ray pulses emitted by compact binary stars, while radio telescopes present us with a map showing the distribution of hydrogen clouds pervading interstellar space. Finally, a gamma-ray telescope scanning the Milky Way would observe occasional powerful bursts of gamma rays from unpredictable directions at intervals of a few weeks. We do not yet understand the cause of these bursts, which last only a few seconds.

Recognizing the importance of new and more powerful observing capabilities, the National Aeronautics and Space Administration has planned a family of observatories, to be launched in the next few years. Under this Great Observatories in Space program, NASA expects to launch the *Hubble Space Telescope*, the *Gamma-Ray Observatory*, the *Advanced X-Ray Astrophysics Facility*, and the *Space Infrared Telescope Facility*. The extensive wavelength coverage they will provide spans most of the spectrum accessible solely from space.

The next thirty years can be expected to present exciting new opportunities for fundamental discoveries through space-based observatories operating at all wavelengths. The size of these facilities will be comparable with the present scale of ground-based observatories. Major new instruments will permit us to observe at sensitivities that are orders of magnitude greater than any currently available.



The Great Observatories will provide substantial advances in our understanding of the universe, but further instrumental advances will be needed to resolve a number of fundamental problems.

While the family of great observatories will undoubtedly provide substantial advances in our understanding of the universe, further instrumental advances will be needed to help resolve a number of fundamental problems. We need to understand the formation of the solar system and of the planets. We need to learn how prevalent planetary systems are in the Galaxy. To date we know of no other system that much resembles ours. While *SIRTF* and *HST* will provide us with information on preplanetary disks surrounding nearby stars and will even be able to detect massive planets surrounding them, large interferometers, or an extremely large single mirror, placed in Earth orbit toward the end of the century, could allow detailed investigations of such planets. These observations could open the way to a search for life on other planets.

Such interferometers — high-spatial-resolution instruments — would also permit the probing of the central engines of quasars, the most luminous objects so far discovered in the universe. Both optical and infrared interferometers of the future could achieve angular resolutions measured in microarcseconds — a resolution that would allow someone on Earth to distinguish the features of a man standing on the Moon.

The angular resolution of *SIRTF* will be relatively limited, so the images of such regions will be fuzzy. The Large Deployable Reflector will attain angular and spectral resolution that will permit study of details as small as 50 astronomical units, or somewhat smaller than the diameter of the solar system, in the nearest star-forming region.

CONCLUSION

For the past thirty years scientific investigation has been neither the only objective of the space program of the United States nor even the dominant one. Instead, establishing a human presence in space and accomplishment of large engineering projects for their own sake have driven a major part of our space program. We propose that, as the nation considers its future in space, the advance of science and its applications to human welfare be adopted and implemented as an objective no less central to the space program than any other.

Provided the nation recovers full access to space after the *Challenger* accident, a large number of scientific missions will be in space by the last years of this century. These missions promise a rich harvest of scientific results that will significantly improve our understanding of the universe. The challenge to the space sciences is to take a bold leap forward after 1995, carrying them closer to answers for the most fundamental questions about the nature of the universe. □

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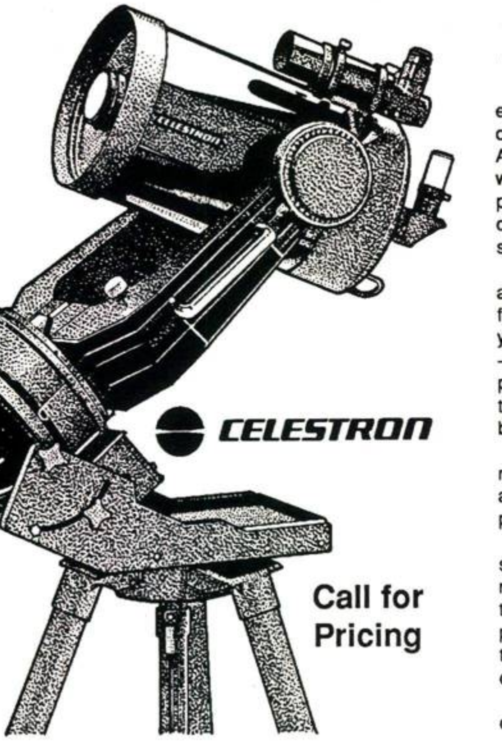

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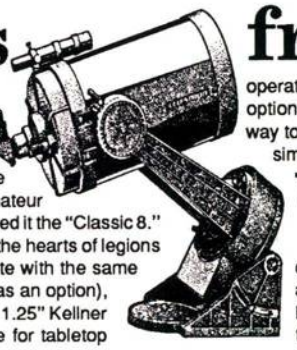

When the Coca-Cola company discontinued original formula Coca-Cola in favor of "new Coke," they learned a valuable lesson. A lot of people preferred *the real thing* – the one-and-only original Coke, not the new upstart. So Coca-Cola brought back original Coke by popular demand, renaming it "Classic Coke." Celestron, not to be outdone, has copied Coke by bringing back the original C8, the 8" scope that started the Schmidt-Cassegrain revolution in amateur astronomy. They've updated the original tried-and-true design and cleverly named it the "Classic 8." The most popular single model telescope in modern astronomy is back, to win the hearts of legions of new owners with its classic simplicity and sensible price. It comes complete with the same superb basic optics as the new Ultima 8 above (Starbright coatings available as an option), a wide 8° field 6 x 30mm finder, stable spur gear AC drive, 25mm multi-coated 1.25" Kellner eyepiece (81x), star diagonal, visual back, dust cover, and equatorial wedge for tabletop operation. An adjustable height tripod is available as an option. At only $999, the Classic 8 is the least expensive way to get Celestron's renowned hand-figured optics. It's simply the most scope you can buy for under $1000!

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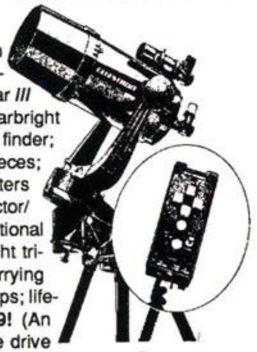

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Send a stamped, self-addressed business-size envelope for our free discount price list, unadvertised specials list, and information about how to pick the right telescope. Or, send $2 (refundable with your first order) and a *large* stamped ($1.05 postage), self-addressed envelope for our full 64-page, 40,000 word catalog that even our competitors admit is the most informative and complete in the telescope industry.

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Here's a partial list of some of the dozens of Celestron scopes and accessories we have in stock, all at low prices that save you big money. Write for our free discount price list that lists your savings on all of them.

Celestron C90 spotting scope, *$650.00 list*	$379.00
Celestron C90 spotting scope, multi-coated, *$710.00 list*	$409.00
Celestron T-adapter or **tele-extender**, *$40.00 list*	$29.50
Celestron LPR Filter #1, for visual backs, *$150.00 list*	$75.00
Celestron LPR Filter #4, for 1.25" eyepieces, *$90.00 list*	$45.00
Celestron LPR Filter #7, for astrophotography, *$170.00 list*	$85.00
Celestron 1.25" 20mm Erfle eyepiece, *$100.00 list*	$44.50
Celestron C60E equatorial refractor, *$438.00 list*	$299.50
Celestron C4.5 equatorial reflector, *$758.00 list*	$449.50

ad-libs
# astronomics
Our tenth year of saving you money.

2401 Tee Circle, Suites 105/106, Norman, OK 73069

Toll-Free Order Line: **(800) 422-7876**
Use (800) 422-7876 for price quotes and credit card orders only.

Tech Questions/Customer Service: **(405) 364-0858**
Use (405) 364-0858 for technical advice and all calls from AK, HI, and OK.

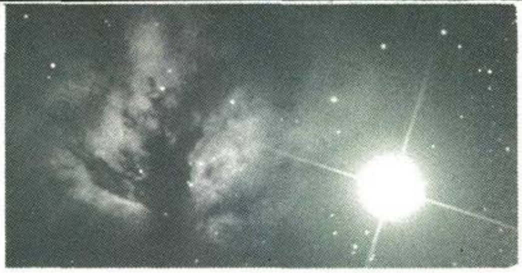
Hours: Monday thru Friday, 10:00 AM to 5:30 PM CST. **Mastercard, Visa, Discover, Optima, and American Express.**

Freight extra on credit card, Canadian, AK, HI, APO, and orders shipped motor freight or air. $2 service charge on orders under $25. $5 COD charge. U.S./Canadian sales only.

Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices. Both Catalogues $3.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



The "Flame Nebula" NGC 2024 in Orion. Also known as the "Christmas Tree" or the "Tank Trucks" nebula. NGC 2024 is seen best usually with either a LUMICON DEEP-SKY or UHC filter. Photo by Don N. Reiners, 16" f/5, 40 min. using hypered 2415 film and a LUMICON 2" EASY-GUIDER.

20mm NAGLER

Also new 12mm & 16mm NAGLERS TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK

Renaissance 4" f/5.5. Telescope	$1395
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	$89
1.8X or 2.5X Tele Vue Barlow Lens	$89
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$190
15mm Wide-Field, 1¼" eyepiece, 65°	$129
19mm Wide-Field, 1¼" eyepiece, 85°	$139
24mm Wide-Field, "superb," 65°	$159
32mm Wide-Field, 2" eyepiece, 65°	$229
40mm Wide-Field, "awesome," 65°	$289
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$185
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$299
20mm Nagler, Type II, 82°, 2" only	$340

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is *ideal for telescopes of 6-16" aperture. It permits* **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount .. **$45**
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$35.00**	**$29.00**
52, 55, 58, 62mm	**$45.00**	**$35.00**
67, 72, 77mm	**$52.00**	**$45.00**
82mm	**$55.00**	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

LUMICON®

2111 Research Dr. #5A, Livermore, CA 94550
For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
Foreign orders add 6% ($8 minimum)
California Residents add 6% tax.
Prices subject to change w/o notice
Hrs: M-F 9am - 5pm; Sat 11am - 3pm

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced silver diagonal mirrors & 1¼" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**				

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$89.50**
2" (1.83" mirror)(see photo above)	**$145.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission=90-97%.

"I CAN SEE THE OWL NEBULA!"
Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Standard	**Premium***
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$59.50**	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$99.50**	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces		**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces		**$199.50**
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium		**$159.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"**	**$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines	**1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe *& simple to use. Easy* HYPER-KIT *includes* a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**

MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller .. **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$89.50**

Guider for Hasselblad **$350**, Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185**, Mamiya 645 **$159**

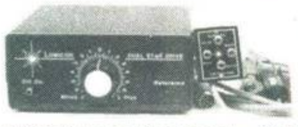
GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) . . . . . . **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**



3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $70
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW
SRV3200
Kodak
SR1600
Scotch
1000

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SRV3200, fastest of all, color neg	24	**$13.95**
Konica SR3200, unhypered	24	**$8.50**
Konica SR400, fine grain color neg	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

LUMICON means INNOVATION

LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Sky Vector ™
ON OFF
2137+490
DIM
RA
DEC
MODE
STAR
LUMICON

LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). Win $10: Identify the object at the coordinates given.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a break-through in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- Digital altitude readout to 1°
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

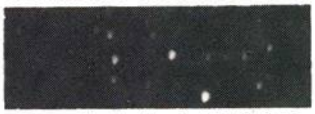
- **No need** to enter latitude, longitude, siderial time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11,C-14 *(Specify)*	**$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)*	**$498**
SKY VECTOR KIT, includes computer, shaft encoders & cables. You must supply adapting hardware. For ATM's only	**$469**

Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects	**$29.95**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
Adapter for Hasselblad	**$185.00**
Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6" telescope.

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$79.50**
3 handles (see photo) for non-rotat. focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

MEADE® TELESCOPES

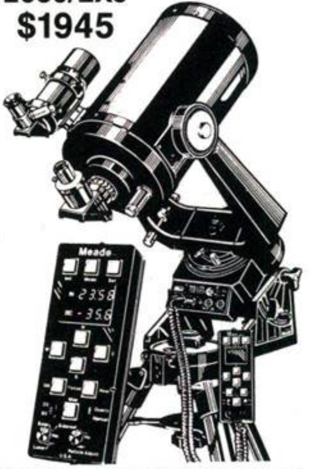
LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

LUMICON ACCESSORIES

2080/LX6 8" f/6 .. $1945
2120/LX6 10" f/6 . $2495

Digital readout system for 2080/2120/LX6	**add $475**
8200 object memory CAT computer	**add $1195**

NEW 2080/LX6 $1945



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

MEADE SCHMIDT-CASSEGRAIN TELESCOPES

2080/LX5, 8" f/10 w/MCOG	**$1589**
2080/LX3, 8" f/10 w/MCOG	**$1389**
2120/LX5, 10" f/10 w/MCOG	**$1995**
2120/LX3, 10" f/10 w/MCOG	**$1799**
2045/LX3 4" f/10 w/LX3 drive	**$795**
#39 declination motor for LX5	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$1195**

MEADE SCHMIDT-NEWTONIAN TELESCOPES

MTS-SN6, 6" f/5, #788 drive	**$589**
MTS-SN6 w/drive, MCOG	**$639**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. mtr	**$189**

MEADE NEWTONIAN TELESCOPES

Model 628C 6" f/8 w/motor, 2" focuser	**$798**
Model 645C 6" f/5 w/motor, 2" focuser	**$698**
Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10,-16	**$109**

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

Filter:	**Bandpass**	**Trans**	**Price**
Ultraviolet	320-420nm	85%	**$35**
Minus Violet	420nm-IR	96%	**$29**
Blue Tricolor	340-470nm	80%	**$35**
Hi Perf. Blue	300-540nm	95%	**$35**
Yellow	480nm-IR	98%	**$18**
Green	490-590nm	60%	**$18**
Orange	560nm-IR	98%	**$18**
Red	600nm-IR	98%	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**
Cyan	340-580nm	95%	**$59**
Adapter for 1¼" eyepieces			**$20**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼" Basic Camera adapter, 2 part system	**$32**
0.96" Basic Camera adapter, 2 part system	**$32**
1¼" prime Focus adapter, fits 1¼" focuser	**$22**
0.96" prime Focus adapter, fits 0.96" focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
2" right-angle version, non-rotating focuser	**$199**
1¼" Deluxe right-angle Super-Finder*	**$279**
2" Deluxe right-angle Super-Finder*	**$309**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$145**
1¼" Amici Prism diag. for correct left-right views	**$59.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

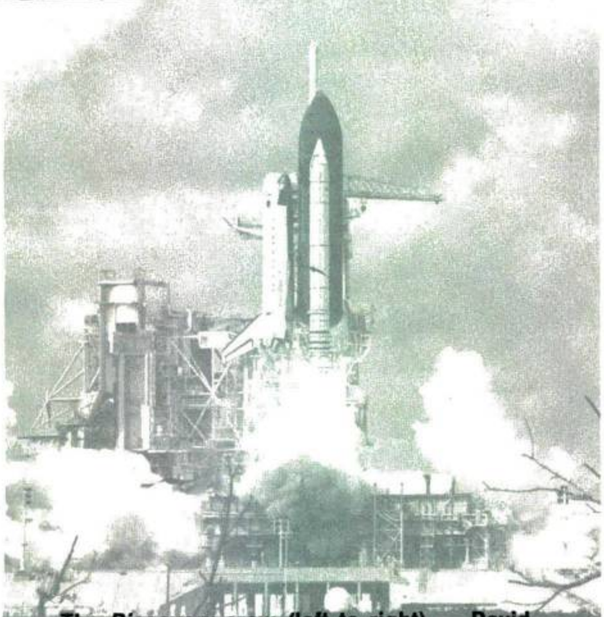
2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for Criterion 4000, 8000	**$26.00**
2" adapter for C-80, C-90, C-100	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

Discovery's 'Cargo of Dreams'

Carrying the fate of the entire space program, *Discovery* lifted off, deployed a satellite, and returned to Earth without a hitch.

by Jeff Kanipe

The *Discovery* crew (left to right) — David Hilmers, John Lounge, Rick Hauck, Richard Covey, and George Nelson — paid tribute to flight controllers by displaying this insignia during a television transmission.



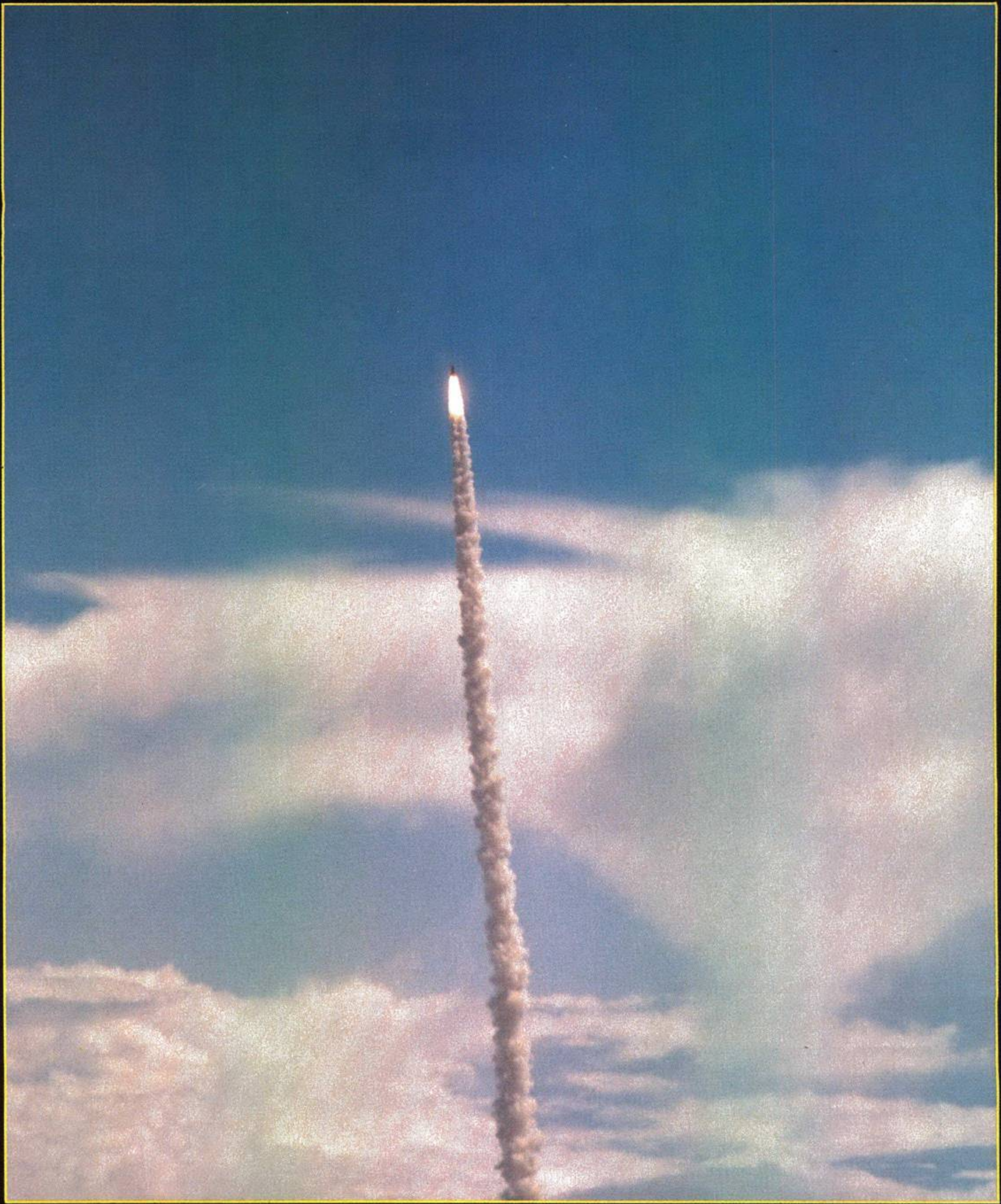
As the space shuttle *Discovery* lifted off the launch pad at Kennedy Space Center September 29, 1988, it was carrying five veteran astronauts, a multimillion-dollar communications satellite, and eleven middeck experiments. *Discovery* was also carrying something else: the fate of the entire U.S. manned space program, perhaps the heaviest burden of all. In the words of one radio commentator, the shuttle was carrying "a cargo of dreams."

It had taken thirty-two months and several million dollars worth of shuttle and rocket booster improvements to return to space again. One of the mission's most important tasks was putting a second Tracking and Data Relay Satellite (TDRS) in orbit, vital to future space missions. The astronauts also conducted a number of science experiments and photographed Earth. But even NASA admitted that the main objective of STS-26 was to launch, fly, and return to Earth in one piece. The five men who flew aboard *Discovery* — Rick Hauck, Richard Covey, John Lounge, David Hilmers, and George Nelson — were professional astronauts, a sober testament to the fact that the four-day flight was a test of the shuttle.

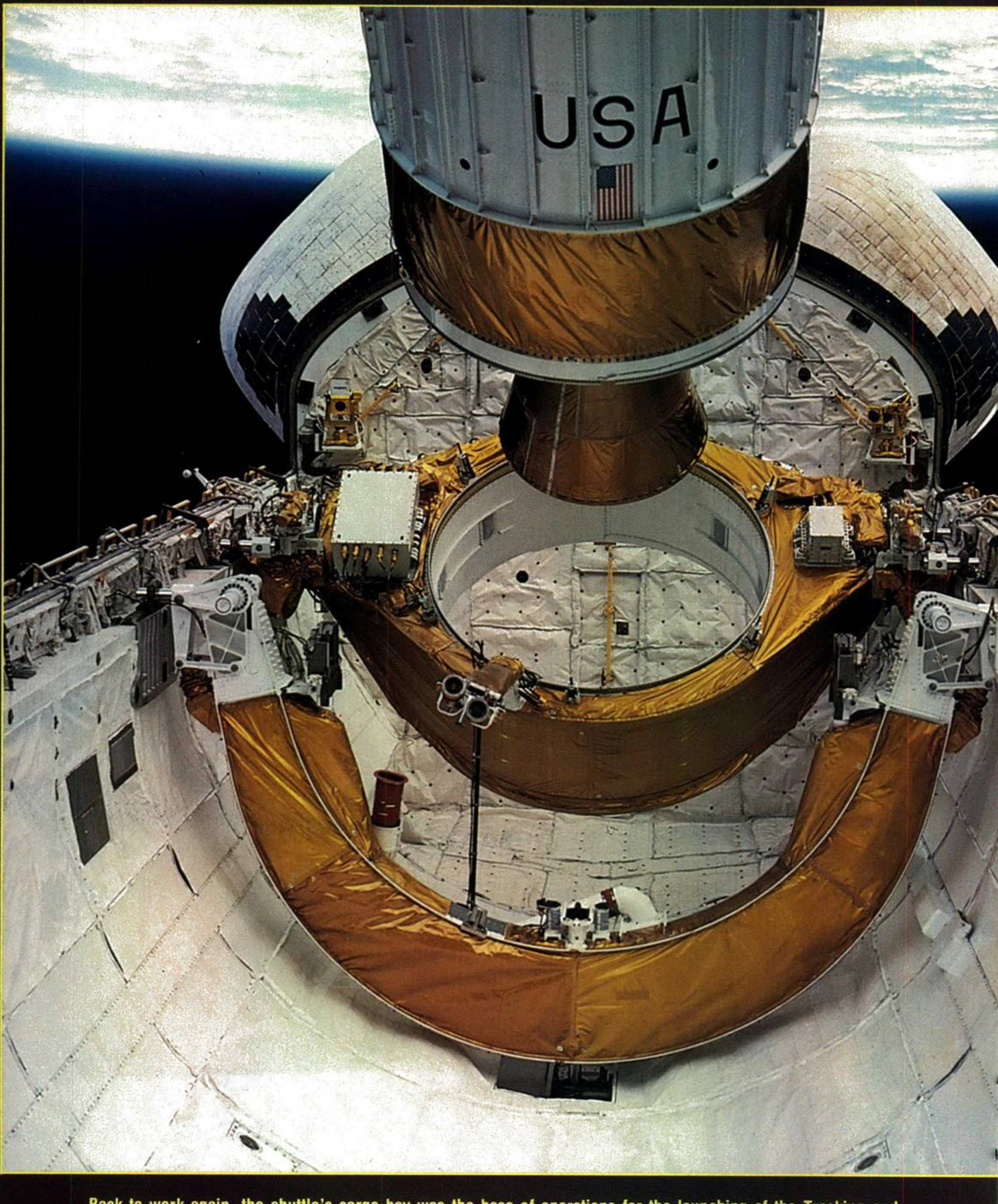
Discovery passed the test when it smoothly touched down four days after launch on the dry Mojave Desert lake bed at Dryden Flight Research Facility in California. But before the lake bed dust had settled, it was clear that Mission STS-26 was more than a success: it was a psychological affirmation. We can fly again!

The mission's first task, accomplished six hours after launch, was the orbital installation of the TDRS. This satellite is the second in a series of three communication-relay spacecraft designed to provide communication and data links between Earth and the shuttle or orbiting spacecraft. The first TDRS was placed in orbit April 5, 1983, from *Challenger*. The second TDRS was destroyed in the *Challenger* accident. The next TDRS will be deployed from *Discovery* during the STS-29 mission, currently scheduled for February 18, 1989. It will serve as an in-orbit spare.

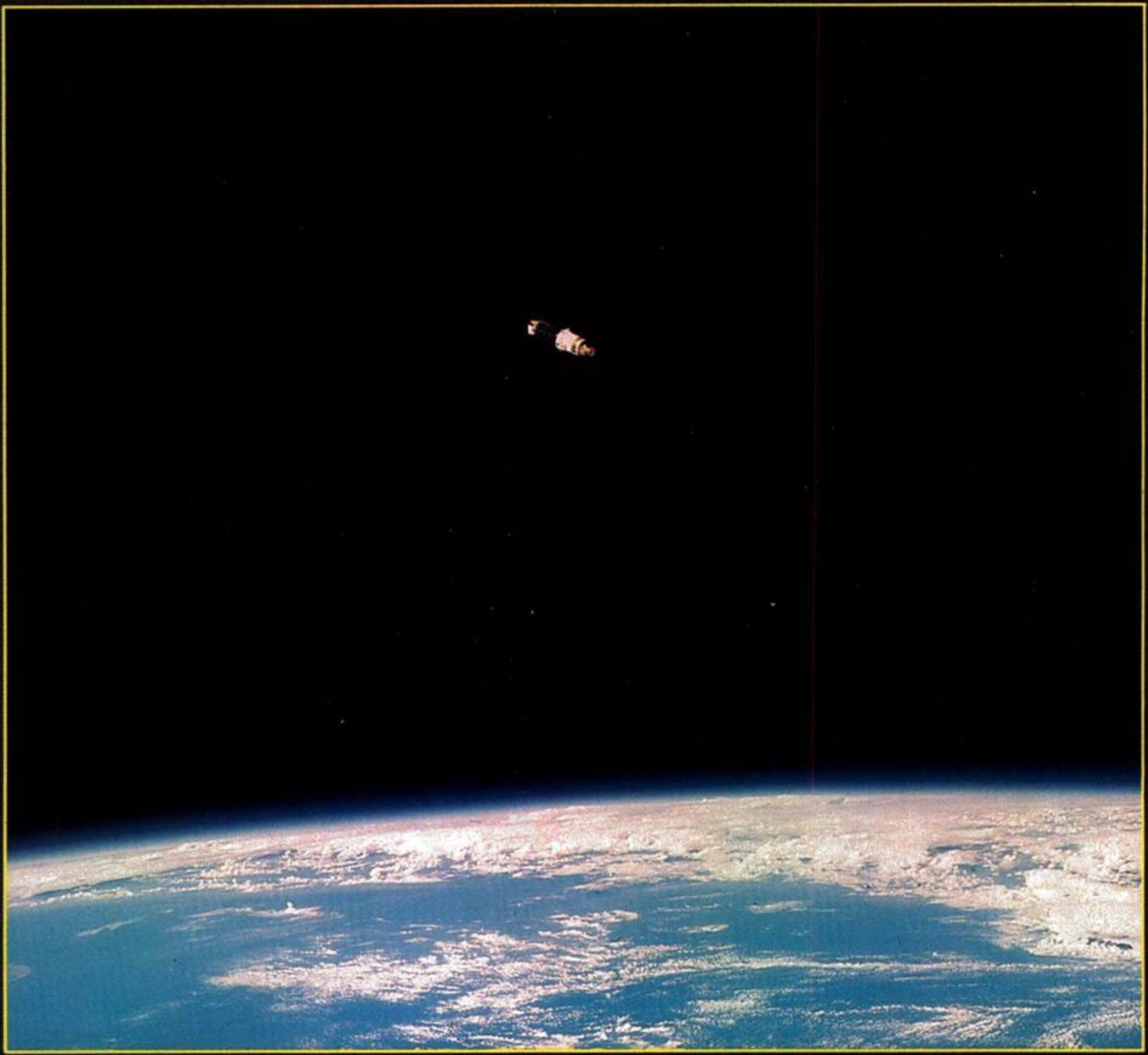
Besides TDRS, *Discovery* carried a number of diverse hands-on experimental payloads. These ranged from voice communications with infrared light to observations of lightning discharges. One package, called the Earth Limb Radiance Experiment, allows scientists to determine the Sun's position below the horizon based on the brightness of the twilight sky. This information should help engineers develop more accurate horizon sensors for geosynchronous communications satellites.



On its way to Earth orbit on September 29, 1988, the 100-ton orbiter *Discovery* was NASA's first manned mission since the *Challenger* accident on January 28, 1986.



Back to work again, the shuttle's cargo bay was the base of operations for the launching of the Tracking and Data Relay Satellite. The above photo shows a close-up of the solid rocket motor that put TDRS into orbit. TDRS drifted out and away from the shuttle (opposite page, top) and in just minutes was *heading* for its destination above the western Pacific Ocean.



Sunrise from the shuttle was photographed by a crew member through *Discovery*'s aft flight deck window.

A crystal grown in zero-g is monitored by mission specialists George Nelson (left) and David Hilmers.

Discovery
United States

Rick Hauck okays the partial pressure suits he and the other crew members wore during launch and return to Earth.

A number of important astronomy payloads are slotted for upcoming shuttle missions (see "Rediscovering Venus and Jupiter" by Stephen Cole on page 24). According to the manifest issued in September 1988, the first planetary mission, *Magellan*, is scheduled to be launched from Earth orbit during the STS-30 mission, which is expected to go up April 28, 1989. *Magellan* will map Venus' surface via high-resolution radar.

Galileo, designed to study Jupiter's atmosphere and explore its satellite system, will finally be sent on its roundabout way to Jupiter during the STS-34 mission scheduled for launch on October 12, 1989. The spacecraft will reach the Jovian system six years later after looping around the Sun twice and Venus once.

On December 11, 1989, STS-34 lifts off carrying the *Hubble Space Telescope*. Once the $1.4 billion telescope is in orbit, it will inaugurate an observing frenzy by astronomers that should precipitate a deluge of new discoveries about the universe.

Ulysses, to be shuttle-launched in October 1990, is the last major solar system mission on the current shuttle manifest. This spacecraft will study the south and north poles of the Sun.

Other astronomy payloads on the shuttle manifest include the *Gamma Ray Observatory* (April 1990), an ultraviolet telescope aboard the Astro 1 mission (March 1990), and the Shuttle High-Energy Astrophysics Laboratory (April 1992).

The horrifying images of the *Challenger* accident have at last been supplanted by the flawless launch of a U.S. space shuttle, by astronauts doing their jobs and cavorting in zero-gravity, and by the noble profile of the shuttle against the bright rim of Earth. *Discovery*'s triumph is a triumph for NASA and a promising new beginning of shuttle operations in space. □

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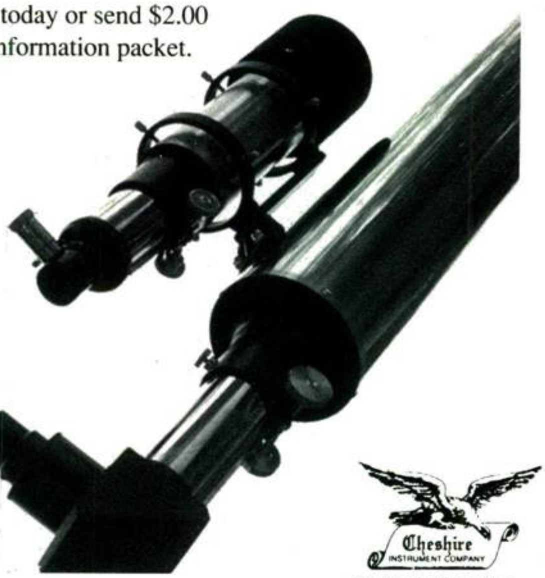

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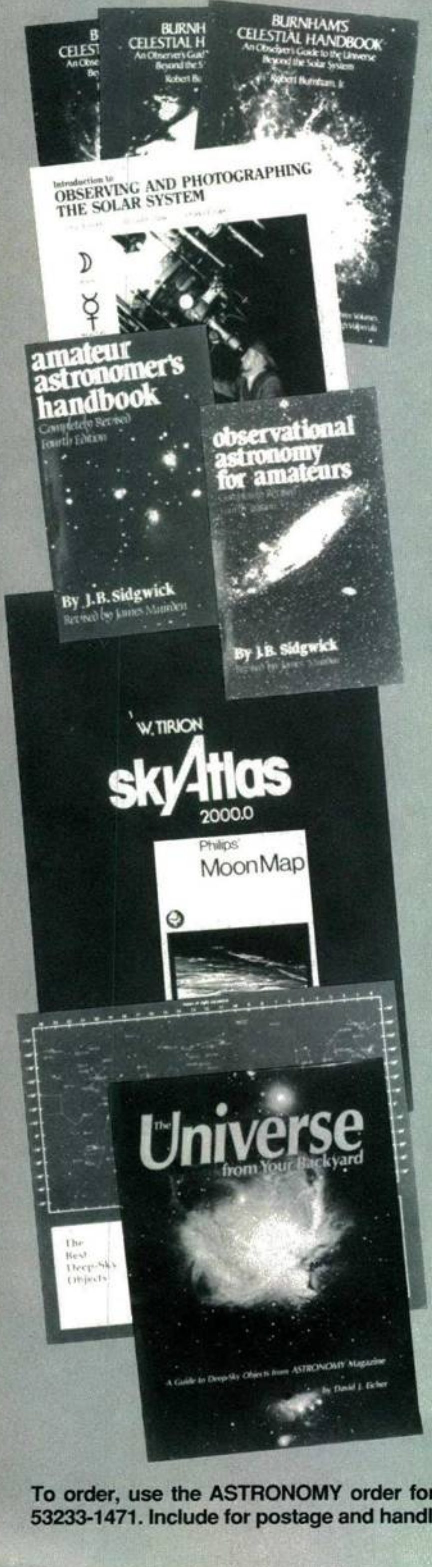
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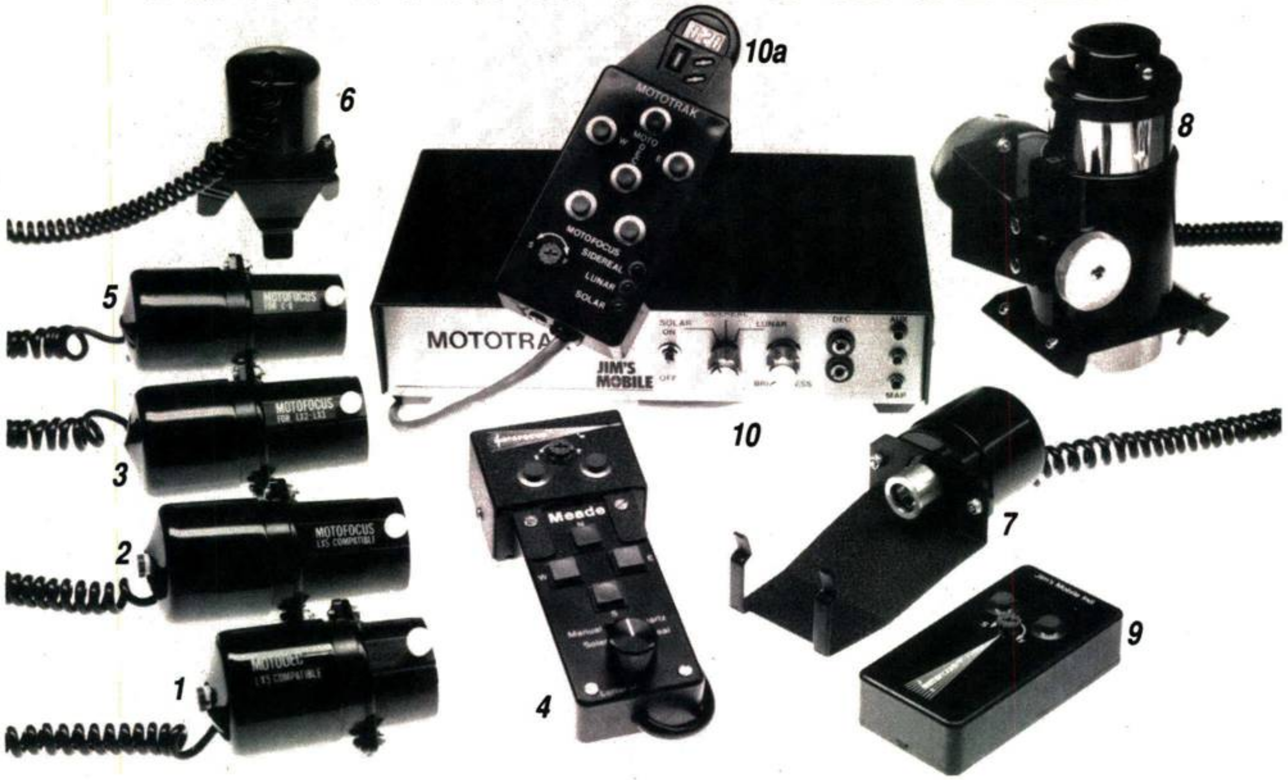

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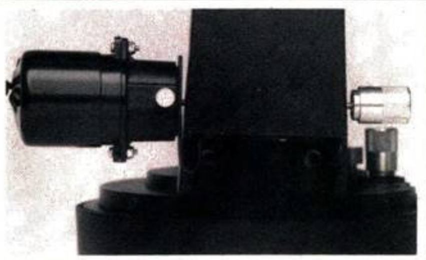

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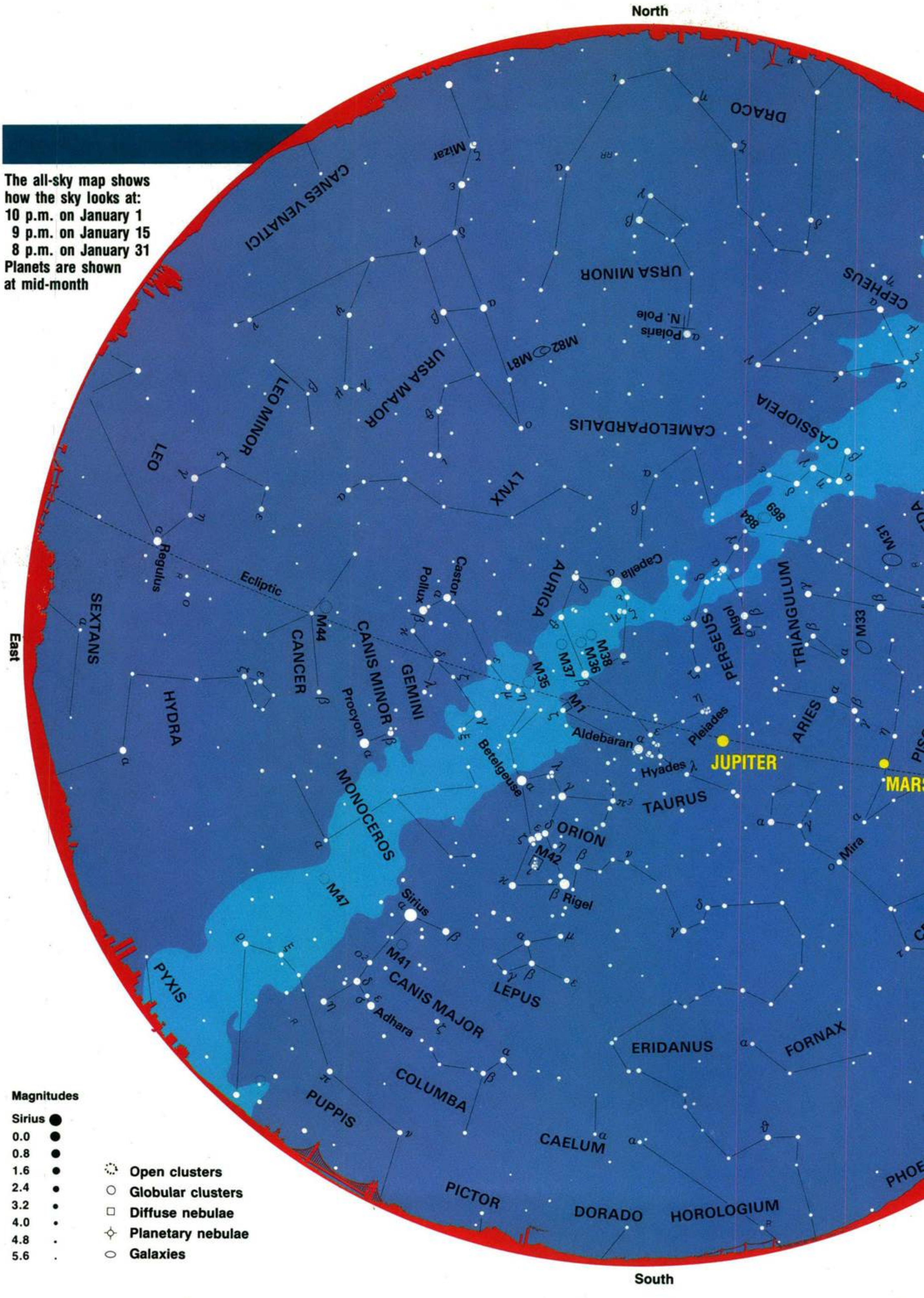
The all-sky map shows how the sky looks at:
10 p.m. on January 1
9 p.m. on January 15
8 p.m. on January 31
Planets are shown at mid-month


North
East
South
DRACO
Mizar
CANES VENATICI
URSA MINOR
N. Pole
Polaris
M82
M81
CEPHEUS
URSA MAJOR
LEO MINOR
CAMELOPARDALIS
CASSIOPEIA
LEO
LYNX
Regulus
Ecliptic
869
884
M31
Capella
AURIGA
Castor
Pollux
SEXTANS
M44
CANCER
CANIS MINOR
GEMINI
M38
M36
M37
M35
PERSEUS
Algol
TRIANGULUM
M33
HYDRA
Procyon
M1
ARIES
Pleiades
Aldebaran
Betelgeuse
Hyades
JUPITER
MARS
MONOCEROS
TAURUS
ORION
M42
Mira
M47
Sirius
Rigel
PYXIS
M41
LEPUS
CANIS MAJOR
Adhara
ERIDANUS
FORNAX
COLUMBA
PUPPIS
CAELUM
PICTOR
DORADO
HOROLOGIUM
PHOE

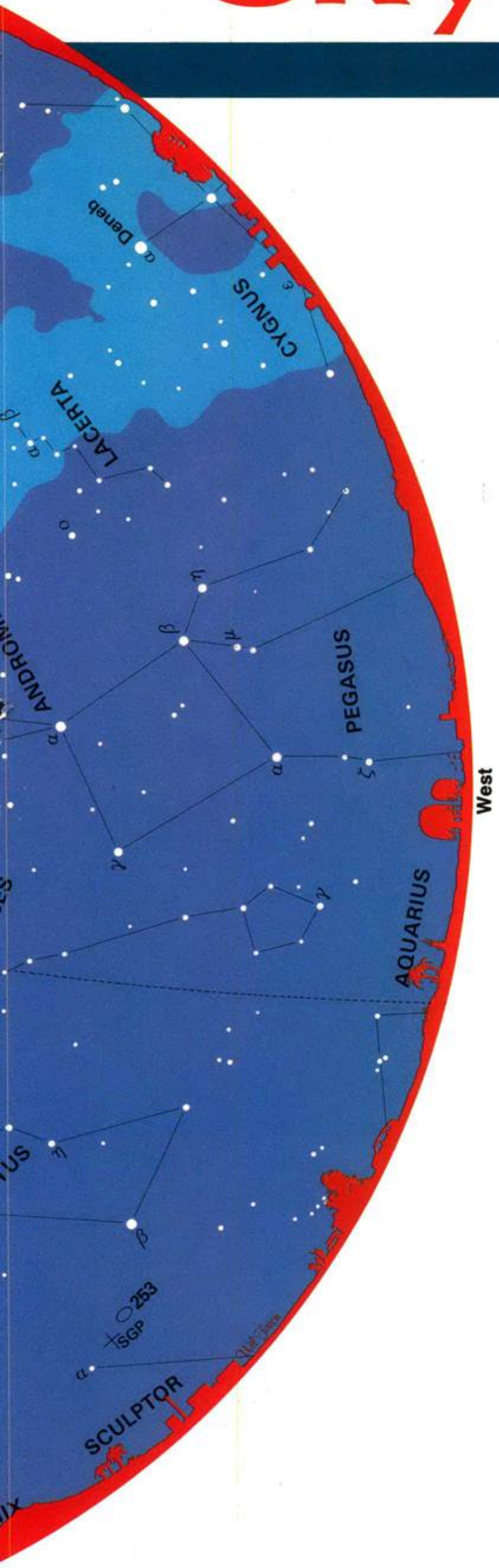
Magnitudes

Sirius	●
0.0	●
0.8	●
1.6	●
2.4	•
3.2	•
4.0	•
4.8	·
5.6	·

- Open clusters
- ○ Globular clusters
- □ Diffuse nebulae
- ⌖ Planetary nebulae
- ⬭ Galaxies

Sky Almanac

JANUARY 1989



QUADRANTIDS PEAK ON JANUARY 3

The Quadrantid meteor shower promises to be one of 1989's best. From a dark-sky location you can expect to see between twenty and a hundred meteors an hour, early on the morning of January 3.

MORNING PARADE OF PLANETS

Venus continues to sink lower in the morning twilight, but as it does so, it succesively passes Uranus, Saturn, Neptune, and Mercury as they emerge from the Sun's glare.

REGULUS OCCULTED ON JANUARY 23

Observers in the eastern half of the United States and far southern Canada can see the waning gibbous Moon pass in front of 1st-magnitude Regulus on the evening of January 23.

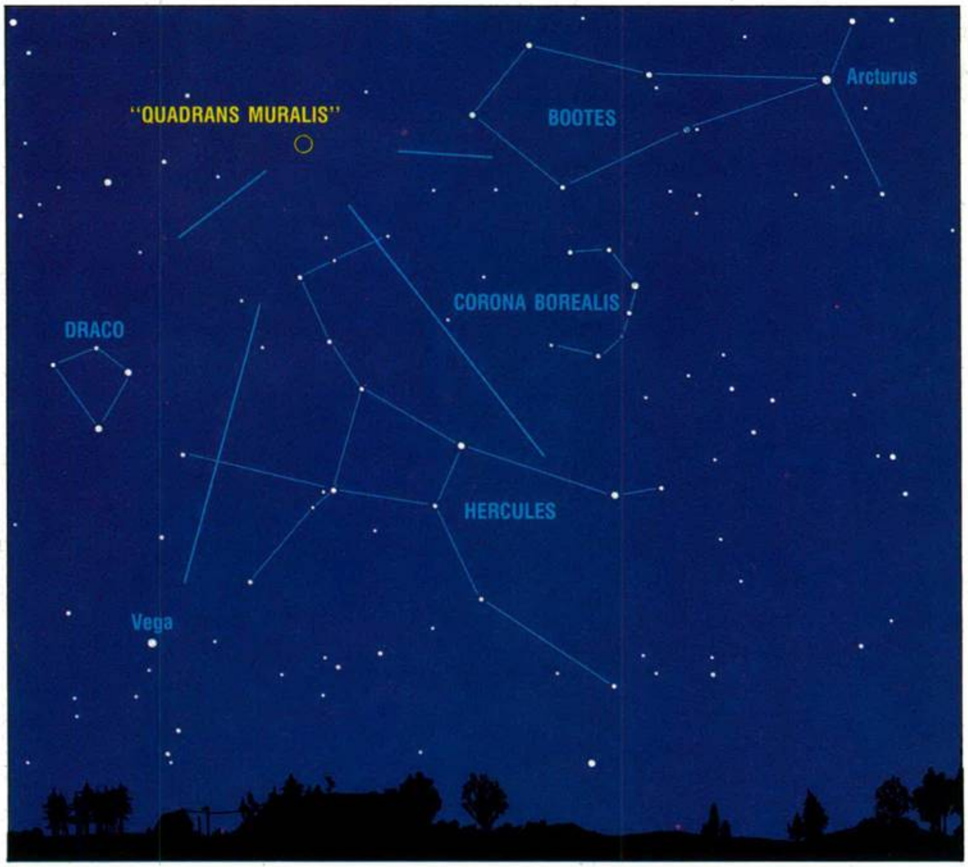
MERCURY AND THE CRESCENT MOON

Mercury reaches greatest elongation on January 8, when it is well placed in the southwest shortly after sunset. That same evening a very slim crescent Moon appears below the elusive planet.

Dates and Times

1 Earth at perihelion (91.404 million miles from the Sun)
3 Quadrantid meteor shower peaks before dawn
4 The Moon passes 0.5° south of Antares, 8 p.m. EST
5 The Moon passes 5° south of Venus, 11 p.m. EST
7 New Moon, 2:22 p.m. EST
8 Mercury at greatest eastern elongation (19°)
9 The Moon passes 1.7° south of Mercury, midnight EST
10 Moon at perigee (227,659 miles from Earth)
12 Venus passes 0.5° north of Uranus, noon EST
14 First Quarter Moon, 8:58 a.m. EST
The Moon passes 4° north of Mars, 5 p.m. EST
16 Venus passes 0.6° south of Saturn, 11 a.m. EST
18 Venus passes 0.9° south of Neptune, 11 p.m. EST
21 Full Moon, 4:33 p.m. EST
23 Regulus occulted by Moon, 9 p.m. EST
24 Mercury in inferior conjunction
26 Moon at apogee (251,718 miles from Earth)
29 Last Quarter Moon, 9:02 p.m. EST
31 Mercury passes 4° north of Venus, 10 p.m. EST

Map Art by Wil Tirion



QUADRANTID METEORS will appear to radiate from a point in northeastern Bootes — the former constellation Quadrans Muralis — in the early morning hours of January 3.

1989'S FIRST METEOR SHOWER

The early days of January bring one of the best but also one of the most elusive meteor showers of the year. The Quadrantid meteor shower can be spectacular, but it is tricky to observe because the number of meteors rises quickly to a peak and then falls off even more rapidly.

The conditions for this year's Quadrantids are favorable for North American observers: the shower's brief peak occurs in the early morning hours of January 3, and the Moon — a waning crescent just four days before New — does not interfere significantly.

On average only the Perseids in August and the Geminids in December produce as many meteors as the Quadrantid shower. (And this year the Moon interferes with both the Perseids and Geminids.) However, the number of Quadrantids varies substantially from year to year. In 1985, for instance, observers reported as many as 235 meteors per hour. On the other hand, the Quadrantids sometimes produce only a few dozen meteors per hour or less.

The shower's radiant lies in northeastern Bootes in the now obsolete constellation of Quadrans Muralis, hence the shower's name. Because this area of sky is still ascending when dawn breaks, be sure to continue watching as close to dawn as you can.

Because they come at one of the coldest parts of winter, the Quadrantids are an especially demanding shower to observe. Dress warmly — or wrap yourself in a good sleeping bag — and settle comfortably into a lawn chair. Every hour or so get up and walk around, have some coffee or hot chocolate, and perhaps eat a sandwich. This will help you keep alert. And remember that you'll see more meteors if you observe from a dark-sky site.

AN EARLY MORNING LINEUP OF PLANETS

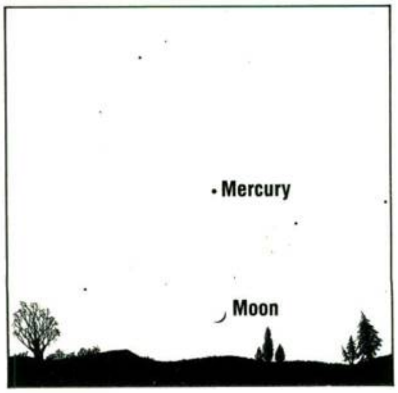
The predawn sky is now littered with planets, but only Venus and Saturn are visible to the naked eye. (You'll need binoculars or a telescope to see Uranus and Neptune.) Venus is now heading into the Sun's glare, while the other three planets are climbing out of it. Thus, the three appear near Venus, each one in its turn, during the course of this month.

Uranus is the first to pass Venus and does so during the morning of January 12. Look for magnitude 5.8 Uranus, thousands of times fainter than Venus, about half a degree south of the bright planet.

On January 16 it is Saturn's turn to pass Venus. Saturn is lost in the morning twilight when January opens but should come into view during the second week of the month. The planet lies about half a degree north of Venus on the 16th, with Venus more than fifty times brighter. Three days later, Neptune appears less than one degree north of Venus. At magnitude 8.0, it can be seen only in binoculars or a telescope.

As an added attraction, watch for Mercury to make an appearance below Venus at the very end of the month. The innermost planet will

A SLIM CRESCENT MOON lies below Mercury on the evening of January 8. Look for the two objects low in the southwestern sky, forty-five minutes after sunset.



pass 4° from Venus on February 1.

THE CLOSEST SUN OF THE YEAR

Earth is at perihelion, its closest approach to the Sun in its yearly orbit, at 5 p.m. EST (2 p.m. PST) on January 1. Then we are about 91.4 million miles from our source of light and heat, compared with over 94.5 million miles in July when we are farthest from the Sun.

Because of this we receive about 7 percent more sunlight in early January than in early July. Yet it is now winter in the Northern Hemisphere. Clearly Earth's distance from the Sun does not cause the seasons! Instead, Earth's seasons are driven almost entirely by our world's 23.5° tilt on its axis. This tilt causes the Northern and Southern Hemispheres to alternately lean most directly toward the Sun. And this month Earth's Southern Hemisphere still benefits from the Sun's more direct rays.

You can see this for yourself by keeping track of the Sun's shifting path across the sky. Just watch the sunrises or sunsets from the same window in your house every few days. Mark the direction where the Sun lies on the horizon with a piece of tape on which you've written the date. You'll notice that even though the Sun is now edging noticeably northward — it reached its southernmost point at the December solstice — it still rises and sets far to the south.

JANUARY'S PLANETS

Mercury came into view in the evening sky late in December. It appears farthest from the Sun on January 8, when it is at greatest elongation, 19° east of the Sun. On that evening a very slim crescent Moon lies just below the −0.6-magnitude planet in the southwestern sky.

Mercury does not linger in the evening sky, however. The planet is closest to the Sun on January 17 and at that time moves swiftest in its orbit. It passes between the Sun and Earth on January 24 and will become visible again, this time before dawn, in early February. With some difficulty you might see Mercury near Venus around January 31.

As darkness falls this month, Mars shines high in the south. Although it is still conspicuous for its brightness and ruddy color, Mars offers us a preview this month of what to expect for much of 1989. That is, Mars grows dimmer and moves into a new constellation.

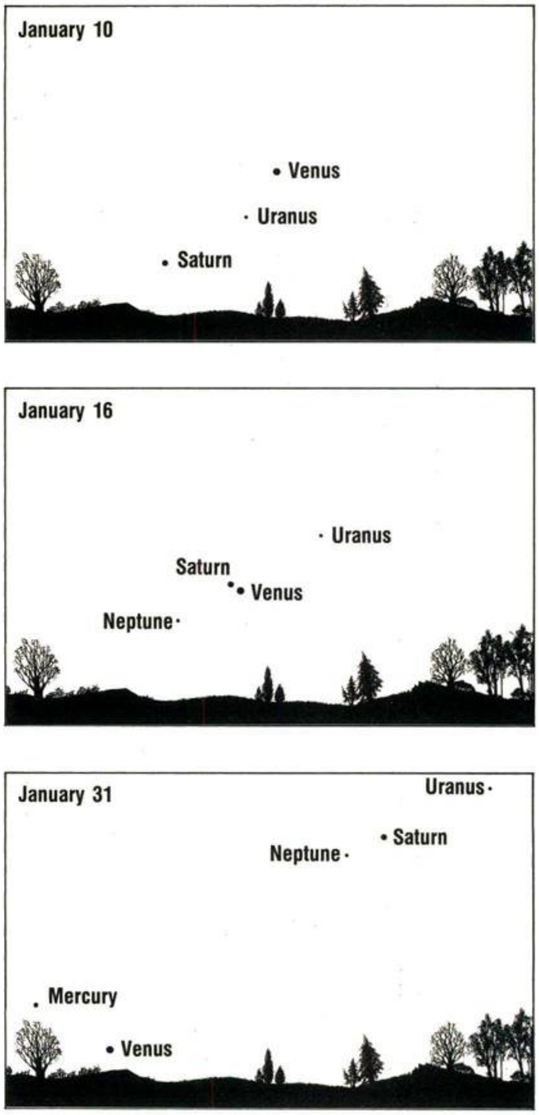
Mars fades by a third during January, from magnitude 0.0 to +0.5. The planet grows fainter because Earth is now rushing ahead of Mars in its smaller orbit. The distance between our two worlds will increase for many months.

Likewise, when the year opens, Mars still appears in Pisces, where it has lingered for several months. But in mid-January it advances to the next zodiacal constellation, Aries. It will move into Taurus by early March and then make a beeline through Gemini, Cancer, and Leo before disappearing into the Sun's glare in August.

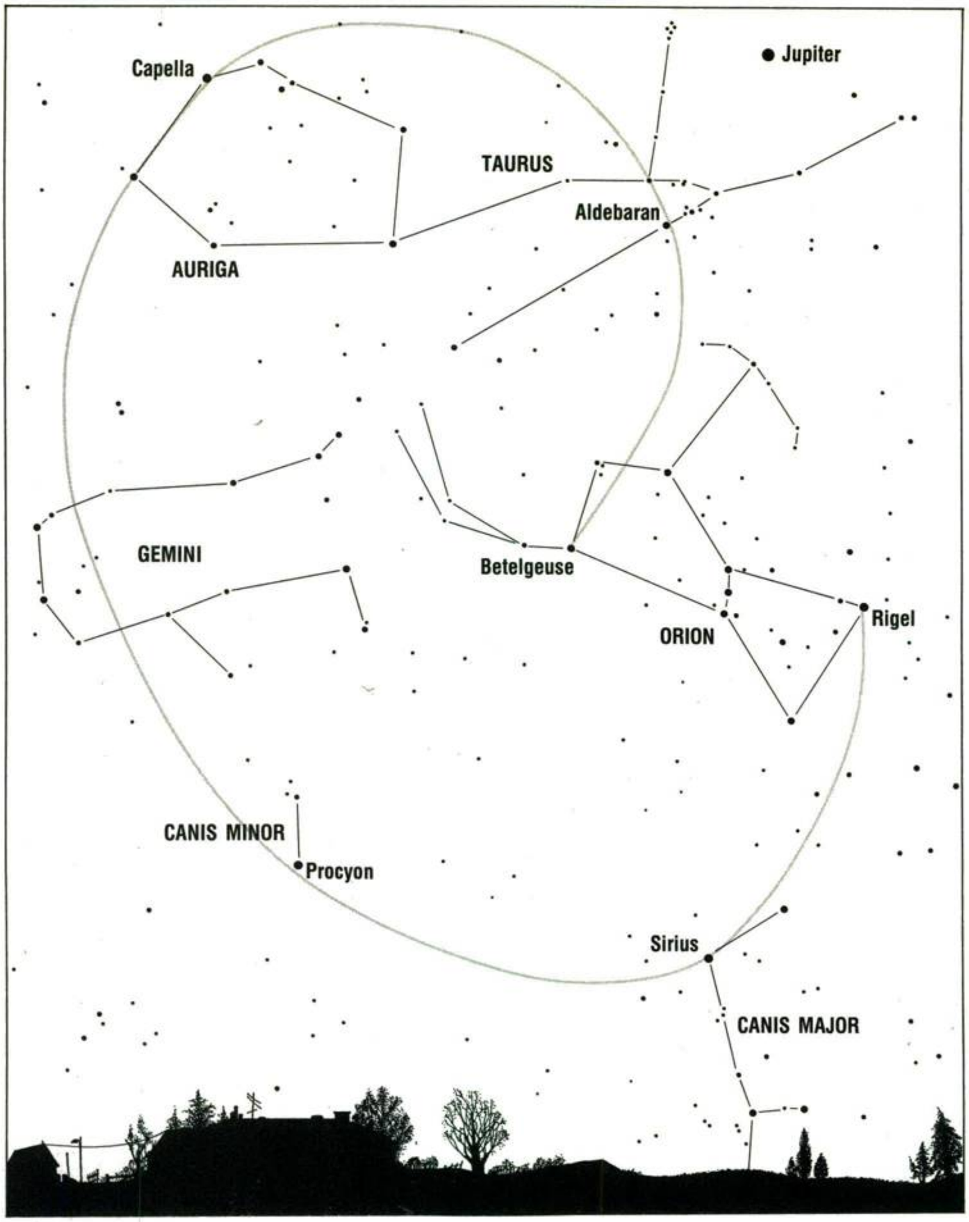
Jupiter remains in the constellation Taurus this month near the Pleiades and Hyades star clusters on the celestial dome. It is high in the southeast when night begins and doesn't set until a few hours before dawn. At magnitude −2.6, Jupiter outshines all the stars.

Earth passed between Jupiter and the Sun in November, when the planet appeared opposite the Sun in our sky, in "opposition." The outer planets generally move toward the east relative to the stars, but for a few months around their oppositions a magnificent illusion occurs. Their progress against the starry background appears to slow and then stop entirely. Then, as though going back for something they'd forgotten, they appear to move toward the west for a time. This month Jupiter's westward, or retrograde, motion ends. On January 20 it is temporarily motionless among the stars of Taurus before it begins to move eastward again.

Venus shines in the southeast before dawn: serene, brilliant, and beautiful as always. Venus is the only planet visible in the predawn sky when the new year begins. Even after Saturn joins it at mid-month, Venus cannot be mistaken for any other object. This month the brightest planet



WATCH VENUS SINK in the southeast each morning as four other planets rise to meet it. Binoculars will help you see Uranus, Saturn, Neptune, and Mercury pass Venus in the twilight glow about thirty minutes before sunrise.



STARS HAVE COLORS, as anyone who looks carefully can see. January evenings are perfect for exploring the colors in the "winter spiral" of stars from blue-white Rigel to reddish orange Betelgeuse.

shines at magnitude −3.9.

Venus is now rather low in the sky at daybreak, and it edges farther into the morning twilight as January progresses. Still, diligent observers should be able to follow it until late February.

Rising out of the twilight by the middle of January, Saturn returns to the morning sky this month and appears near Venus on the 16th. The planet is relatively inconspicuous at magnitude +0.5, but it will rise earlier and grow steadily brighter until its July opposition. Saturn is now in the constellation Sagittarius where it will remain throughout 1989.

JANUARY'S STARRY SKY

January brings with it an age-old controversy among astronomy enthusiasts: Should we brave the cold to observe the sky, or settle back in a nice warm armchair to read a good book about astronomy?

This month, simply by looking outside, you can do a little of both. There's an astronomy lesson waiting for you in the evening sky, one that involves the brightest stars of winter.

The stars are Sirius, Rigel, Betelgeuse, Aldebaran, Capella, and Procyon. Although these six stars reside in five different constellations, they are easy to see as a large spiral pattern in the south and overhead on winter evenings. And this year Jupiter appears among these stars near ruddy Aldebaran, conspicuously brighter than them all.

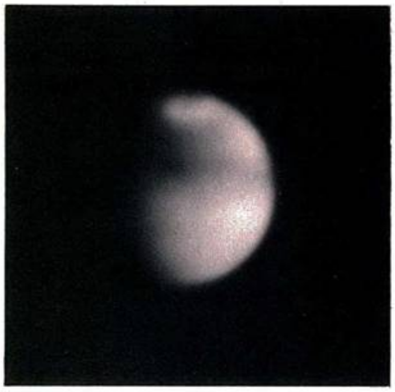
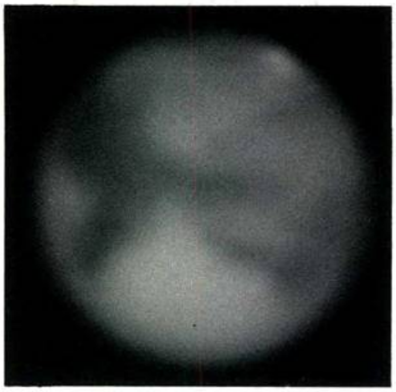
The lesson of these glittering winter stars is in their colors, which span nearly the entire range possible for normal stars. Each star's color, in turn, is a consequence of the star's temperature. The stars on our list have surface temperatures that range from about 3500 kelvins to 10,000 kelvins. Astronomers use temperature to classify stars into spectral types — the seven primary spectral types, in order of decreasing temperature, are identified by the letters O, B, A, F, G, K, and M.

The winter stars in our spiral pattern represent nearly all the spectral types and, if you look carefully, you can see the difference in their colors. (Binoculars will help you distinguish the colors, although you can notice the trend with your naked eye.) Our first stop is Rigel — a blue-white B star in Orion. Next is Sirius in Canis Major, which is a white A star, and then Procyon in Canis Minor, a yellow-white F star. Skip over the stars of Gemini and move onto Capella in Auriga, a yellow G star, and then Aldebaran in Taurus, a yellow-orange K star. The spiral ends at Betelgeuse, back in Orion, which is a reddish orange M star. If you glance back to Rigel now, you'll see just how much color contrast exists among these stars.

Take a look some night this month and try to notice the colors of these stars. You'll enjoy "reading" this live astronomy textbook in the winter sky. ☐

Through the Eyepiece by Rick Shaffer

OBSERVING A GIBBOUS MARS

A GIBBOUS MARS will greet telescopic observers this month. Donald C. Parker captured Mars at this phase (left) last June. For comparison, Rick Dilsizian shot a much larger and 100 percent illuminated Mars at opposition (right) in September.

Mars continues to shrink in the eyepiece as 1989 opens. Your best views of the Red Planet should have come last September and October when the Martian disk was over 20″ in diameter. Even though Mars' disk is now less than 10″ across and shrinks to just 7.4″ by month's end, January is still a good month to observe the Red Planet.

There are several reasons for the continuing good views of Mars' surface. First, Mars is conveniently located in the evening sky this month, crossing the meridian at the end of twilight. Second, if you've been observing Mars regularly during this apparition, your eye-brain combination will be better able to discern subtle details on the planet's surface. This means you should see more this month, three to four months after opposition, than you did when Mars was last this size — three to four months before opposition. Use the table at right along with the map on page 78 of the December issue to identify the various Martian surface features.

In addition, Mars reaches quadrature this month, so the Red Planet appears noticeably gibbous through a telescope. A superior planet — one with an orbit larger than Earth's — is at quadrature when it is 90° from the Sun in our sky. This configuration happens twice each apparition, once before opposition and once after. At these times we see a larger portion of the planet's unilluminated side than at any other time.

During January Mars appears 88 percent lit — a pronounced gibbous shape that should be obvious in your telescope. The maximum phase effect occurs on January 10. On that day the planet's equatorial diameter is 8.8″. However, the apparent angular diameter that is "lost" because the disk is not fully illuminated from our perspective is 1.1″. Thus, on January 10, Mars is 8.8″ in polar diameter but appears to be only 7.7″ (8.8″ − 1.1″) in equatorial diameter.

MARTIAN CENTRAL MERIDIANS

Date	Central Meridian
Jan. 1	94°
Jan. 6	46°
Jan. 11	357°
Jan. 16	309°
Jan. 21	260°
Jan. 26	212°
Jan. 31	163°

This table gives the central meridian on Mars at 2 UT on the date shown (9 p.m. EST, 6 p.m. PST the day before).

REGULUS DISAPPEARS — AGAIN

On the night of January 23/24 observers in the eastern United States and extreme southern Canada can see the 16.4-day-old Moon pass between themselves and the 1st-magnitude star Regulus. The occultation is visible south of a line that runs through central Maine, northern lower Michigan, central Wisconsin, southern Minnesota, and the South Dakota-Nebraska state line, and east of a line that runs from western Nebraska through eastern Colorado, the Oklahoma Panhandle, and western Texas. In this region observers with telescopes can see the bright limb of the waning gibbous Moon occult Regulus and then see the star reemerge from behind the Moon's dark limb. Observing a bright-limb disappearance is very difficult with the naked eye or binoculars but quite easy with a telescope at magnifications of 100x or more. The dark-limb reappearance is trickier observationally because the event occurs with no warning, so even a momentary blink of your eyes could cause you to miss it. See the table on page 70 for the specific times of these events in various cities.

Observers in the southern part of North America will also see Regulus occulted by the Moon on April 15. Indeed, Regulus is occulted for observers somewhere on our planet a total of ten times this year. But Regulus isn't the occultation champ among bright stars this year. Antares is occulted by the Moon every lunar month in 1989 — a total of thirteen times!

Why is 1989 open season on Regulus and Antares? It's a bit like the seventeen-year locusts, only the occultation cycle repeats itself every 18.6

years. The Moon's orbit is inclined about 5° to the plane of the ecliptic, which is the plane defined by the apparent path of the Sun across the sky. (It's really the plane of Earth's orbit around the Sun.) If the Moon's orbital plane were fixed with respect to the ecliptic plane, the Moon would occult the same objects over and over. If one of those objects were the Sun, we would have twelve or thirteen solar eclipses every year! However, the plane of the Moon's orbit does shift relative to the ecliptic. This motion is called precession, and it is caused by the Sun's gravitational pull on the Earth-Moon system. The points where the Moon's orbit and the ecliptic plane intersect precess one complete revolution around the sky in a period of 18.6 years.

This slow precession of the Moon's orbit allows the 1/2°-diameter disk of the Moon to pass in front of specific stars many months in a row. Thus, the four 1st-magnitude stars that lie near the Moon's orbit — Regulus, Antares, Spica, and Aldebaran — take turns being occulted over the 18.6-year cycle. This year is Regulus and Antares' turn.

TELESCOPIC PLANETS

Mercury makes an evening appearance in the first half of January. Because the planet is far south of the celestial equator, it hangs low above the southwestern horizon for North American observers. However, Mercury sets seventy-five minutes after sunset or later between New Year's Day and January 17, so you should have a good view of it as it grows from less than 6″ in diameter to over 8″ across and its phase shrinks from over 80 percent lit to less than 30 percent lit.

January is Venus' next-to-last month in the morning sky — the planet rises only forty minutes before the Sun by month's end. Venus presents a slowly changing phase during January because it is almost on the opposite side of the Sun from our perspective. Just as its phase changes slowly, so does its diameter, which only diminishes from 11.0″ to 10.3″ during the month. The planet's brightness remains constant at magnitude −3.9 throughout January as Venus' increasing distance is neatly balanced by its disk being slightly more fully illuminated.

Venus makes its impending departure from the morning sky memorable, however, because it passes less than a degree from Uranus, Saturn, and Neptune on January 12, 16, and 19, respectively. These events offer a rare opportunity to observe a bright inferior planet in the same low-power field with three of the much more remote gas giants. The low-power "eyepiece" views on page 71 give you an idea of the relative sizes and separations of the planets for each of the three events. Unfortunately January is not a good month to view Saturn, Uranus, and Neptune for themselves: they lie too close to the horizon and are immersed in the twilight glow until late in the month. Your view of these three outer planets will be much better in the coming months.

The three close conjunctions also offer interesting photographic opportunities for those who have their own darkroom or can sweet-talk a commercial photofinisher into special printing. The large difference in the brightnesses of the objects (Venus is fifty times brighter than Saturn and over one thousand times brighter than

OCCULTATION OF REGULUS

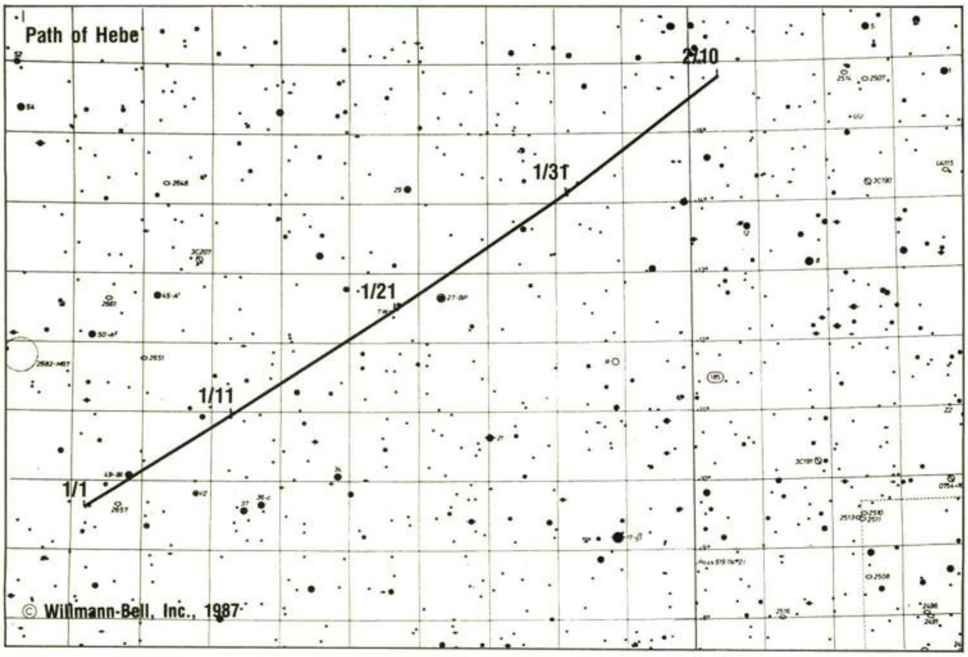
City	Disappears	Reappears
Halifax	10:18 AST	10:40 AST
Montreal	9:15 EST	9:29 EST
Toronto	9:03 EST	9:34 EST
Washington	8:50 EST	9:45 EST
Atlanta	8:41 EST	9:43 EST
Miami	8:40 EST	9:46 EST
Chicago	7:56 CST	8:33 CST
Austin	—	8:38 CST
Kansas City	—	8:34 CST

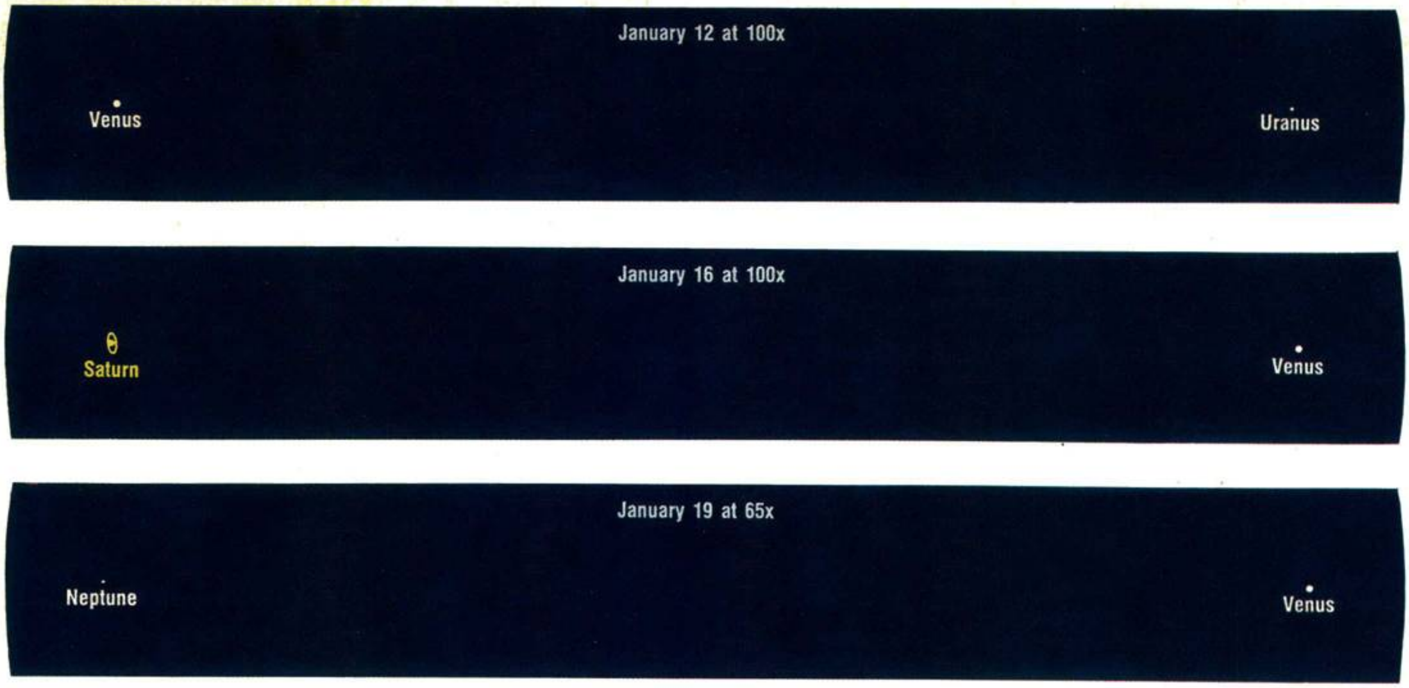
This table gives times on the evening of January 23, when Regulus disappears and reappears from behind the Moon. A dash indicates the event is not visible.

COORDINATES FOR HEBE

Date	R.A. (2000)	Dec.
Jan. 1	8h47.0m	9°37′
Jan. 11	8h38.9m	10°56′
Jan. 21	8h29.3m	12°29′
Jan. 31	8h19.3m	14°09′
Feb. 10	8h10.4m	15°46′
Feb. 20	8h03.4m	17°14′

OBSERVE ASTEROID 6 HEBE at its brightest during January and February. The minor planet reaches opposition in Cancer the night of January 24/25. (Positions are given for 0 UT.)





VENUS HAS THREE CONJUNCTIONS this month — with Uranus, Saturn, and Neptune. These views show how each event will look in an 8-inch f/6 reflector at the magnification given. North is to the left.

Uranus or Neptune) will require some elaborate masking or dodging of Venus' image while the final print is being made.

Having reached opposition more than a month ago, Jupiter is now a convenient evening object. Its disk shrinks from 46″ in diameter at the beginning of the month to 42″ by the end of January, and its brightness drops slightly from magnitude −2.7 to −2.5. This month is a prime observing period for fanciers of the Jovian cloud tops because Jupiter transits at mid-evening, which puts it near the zenith for long periods. And with Jupiter near the zenith you have the potential for good seeing because you don't have to look through as much of Earth's atmosphere.

COMETS FOR THE TELESCOPE

Unfortunately, none of the comets in the inner solar system this month is predicted to be visible in the average backyard telescope. However, new comet discoveries are possible at any time, and such comets occasionally put on nice shows. One recent example was Comet Machholz, which was bright enough to see with the naked eye last September.

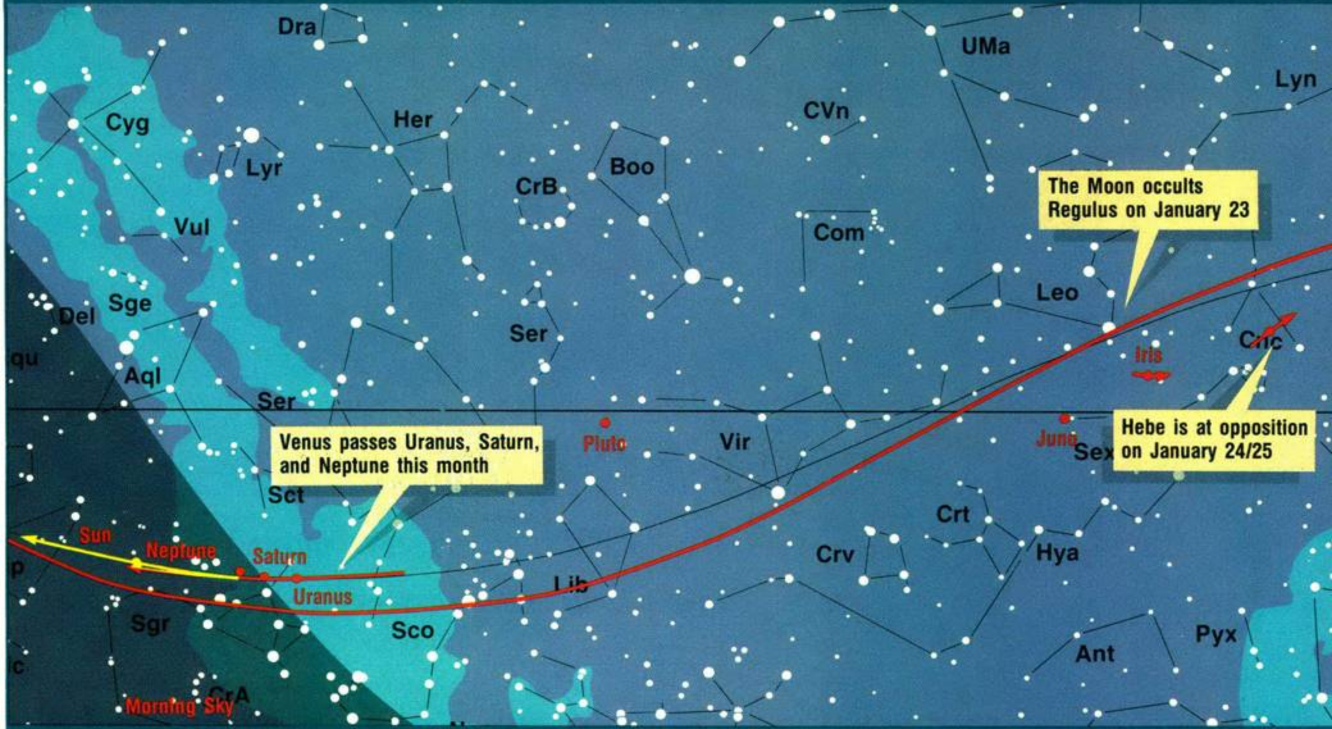
The reason I'm telling you about a September 1988 comet in the January 1989 column is to illustrate an important point: the view people like Don Machholz have through their comet seekers is radically better than the view I have through my crystal ball! Intrepid comet hunters will always be discovering comets long after ASTRONOMY goes to press with an issue of the magazine but before that issue reaches its readers. You read nothing of Comet Machholz in September's Through the Eyepiece because I wrote it *before* the comet was discovered.

To protect yourself from missing a new comet or other observational discovery, you must depend on the news media, word of mouth, or the International Astronomical Union circulars issued by the Smithsonian Astrophysical Observatory. (You might suggest that your astronomy club subscribe to the IAU circulars. For more information contact the Central Bureau for Astronomical Telegrams, Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138.)

ASTEROIDS IN THE EYEPIECE

Asteroid 6 Hebe reaches opposition on the night of January 24/25. Hebe, a chunk of planetary debris 201 kilometers across, lies in Cancer throughout January and shines at magnitude 8.8 at opposition. Use the table of coordinates or the finder chart on page 70 to locate the asteroid's approximate position. Observe this area of sky at low magnification and photograph or sketch the starfield. Then repeat your observation a night or two later; the point of light that moved is Hebe. ☐

The Solar System January 1989



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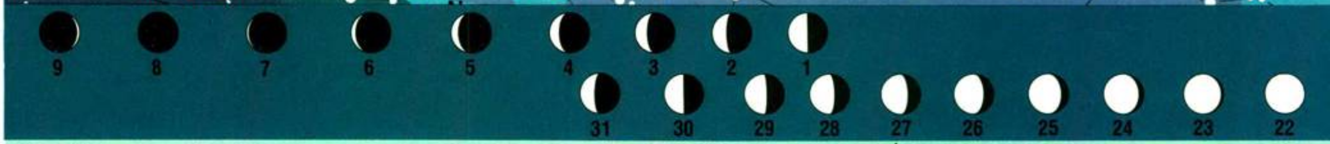
Morning Sky

The Moon occults Regulus on January 23

Hebe is at opposition on January 24/25

Venus passes Uranus, Saturn, and Neptune this month



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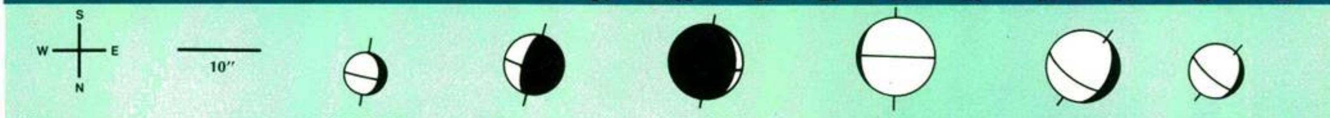
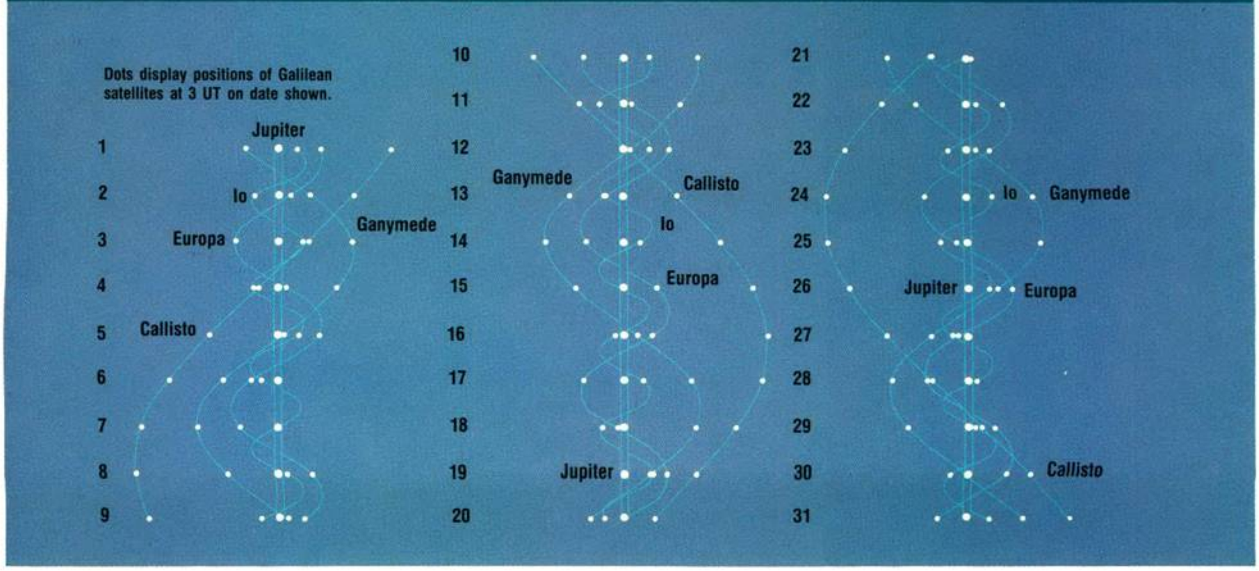
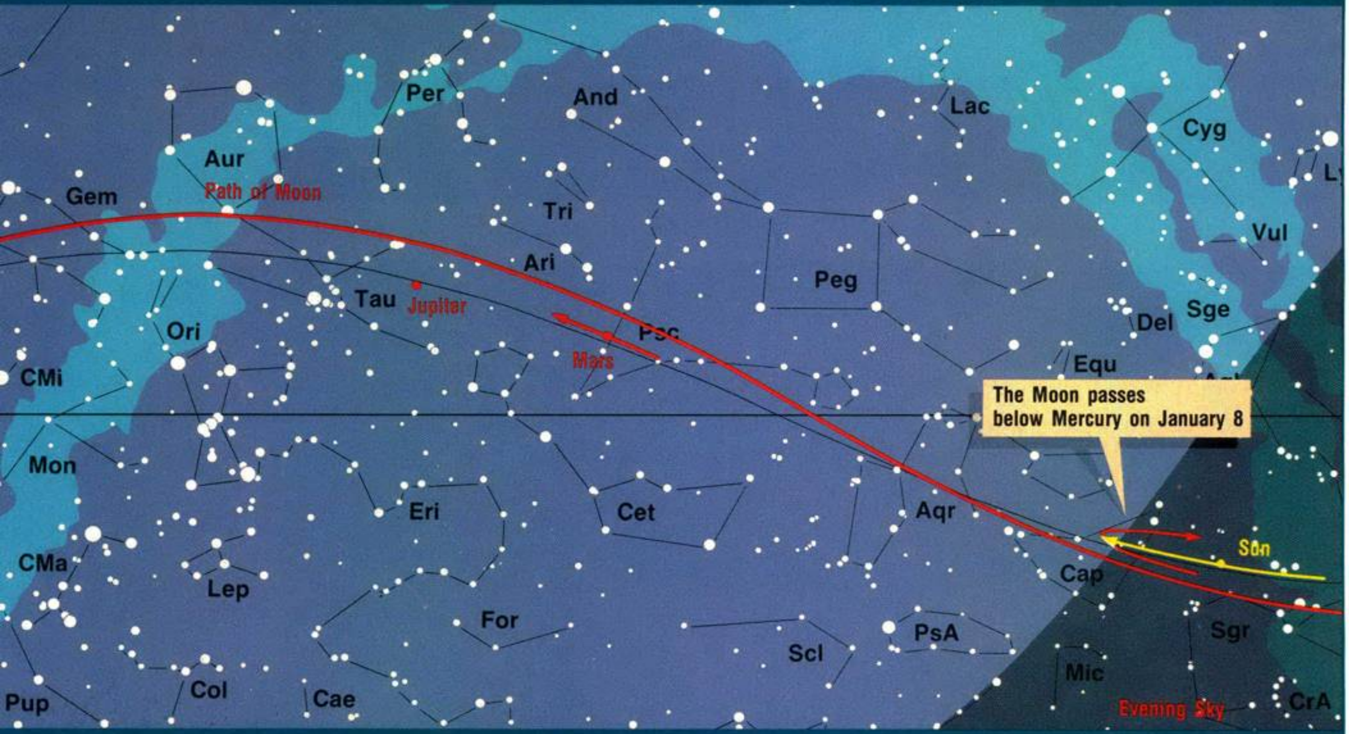


Planet	MERCURY	MERCURY	MERCURY	VENUS	MARS	MARS
Date	January 1	January 15	January 31	January 15	January 1	January 31
Magnitude	−0.7	+0.2	+2.0	−3.9	0.0	+0.5
Angular Size	5.72″	8.13″	9.84″	10.6″	9.6″	7.4″
Illumination	82%	32%	11%	95%	88%	88%
Distance (AU) from Earth	1.176	0.827	0.683	1.574	0.976	1.259
Distance (AU) from Sun	0.370	0.309	0.357	0.726	1.497	1.536
Right Ascension (2000.0)	19h59.9m	20h56.8m	19h59.3m	18h23.8m	1h14.4m	2h16.3m
Declination (2000.0)	−22°32′	−16°33′	−17°04′	−23°06′	8°28′	14°44′

Jupiter's Moons



Dots display positions of Galilean satellites at 3 UT on date shown.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Path of Moon
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Sge
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Equ
The Moon passes below Mercury on January 8
Mon
Eri
Cet
Aqr
Sun
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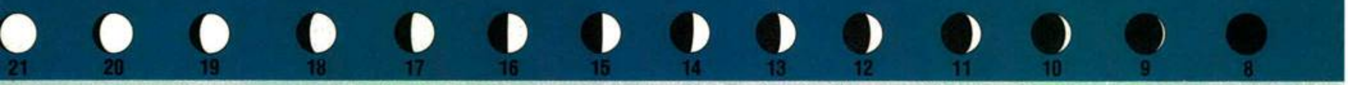
Evening Sky
CrA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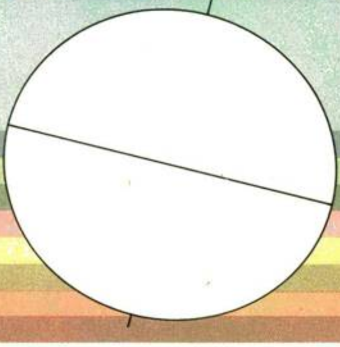
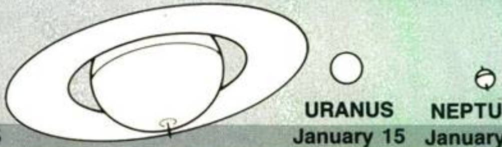
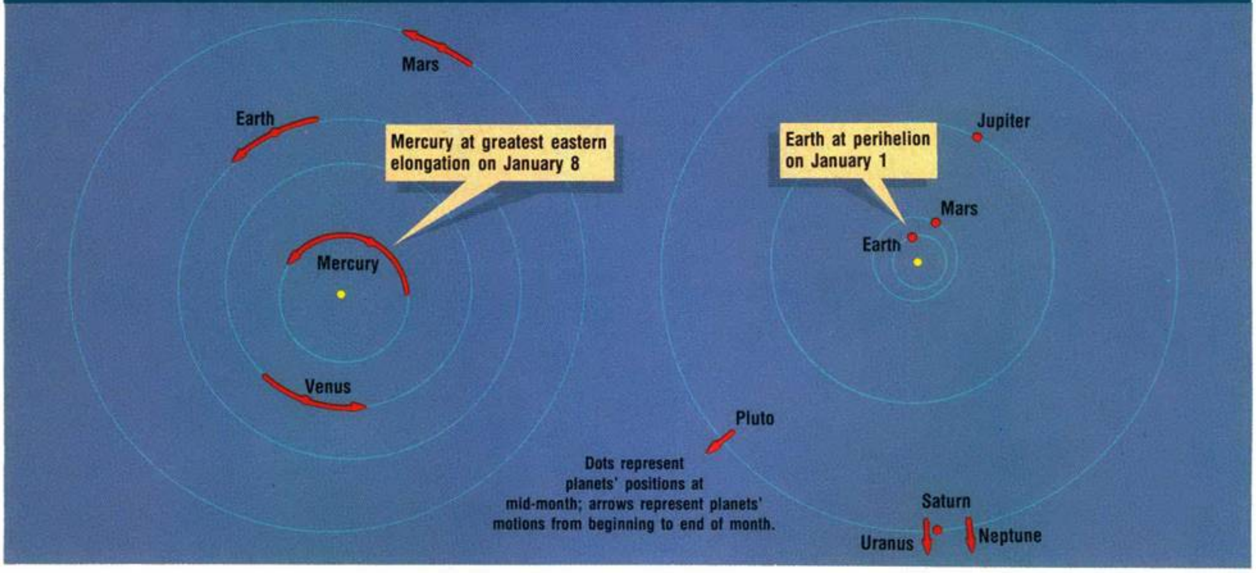




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
January 15	January 15	January 15	January 15	January 15
−2.6	+0.5	+5.8	+8.0	+13.7
44.2″	15.1″	3.5″	2.1″	0.1″
99%	100%	100%	100%	100%
4.454	10.976	20.224	31.171	29.968
5.036	10.043	19.317	30.219	29.658
3h36.7m	18h32.0m	18h11.9m	18h45.8m	15h08.4m
18°31′	−22°32′	−23°38′	−22°07′	−1°18′

The Planets in Their Orbits


Mars
Earth
Mercury at greatest eastern elongation on January 8
Mercury
Venus
Earth at perihelion on January 1
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

CHALLENGER
7
CRIPPEN
FABIAN
HAUCK
RIDE
THAGARD

STS 7
Enlarged
to show
detail.

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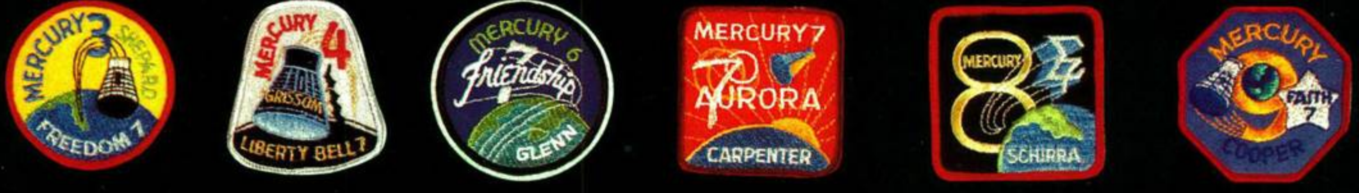
MERCURY 3 SHEPARD FREEDOM 7
MERCURY 4 GRISSOM LIBERTY BELL 7
MERCURY 6 Friendship 7 GLENN
MERCURY 7 AURORA CARPENTER
MERCURY 8 SCHIRRA
MERCURY 9 FAITH 7 COOPER

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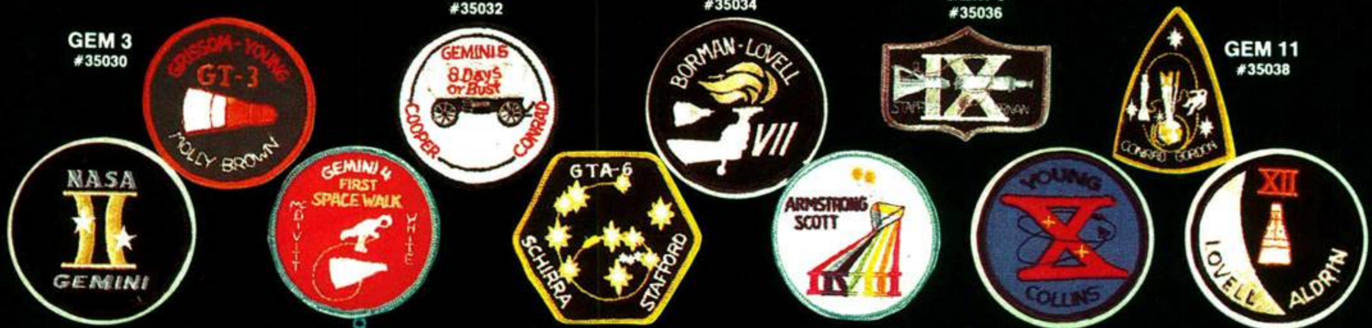
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IX
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XII LOVELL ALDRIN

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GEM 7 #35034
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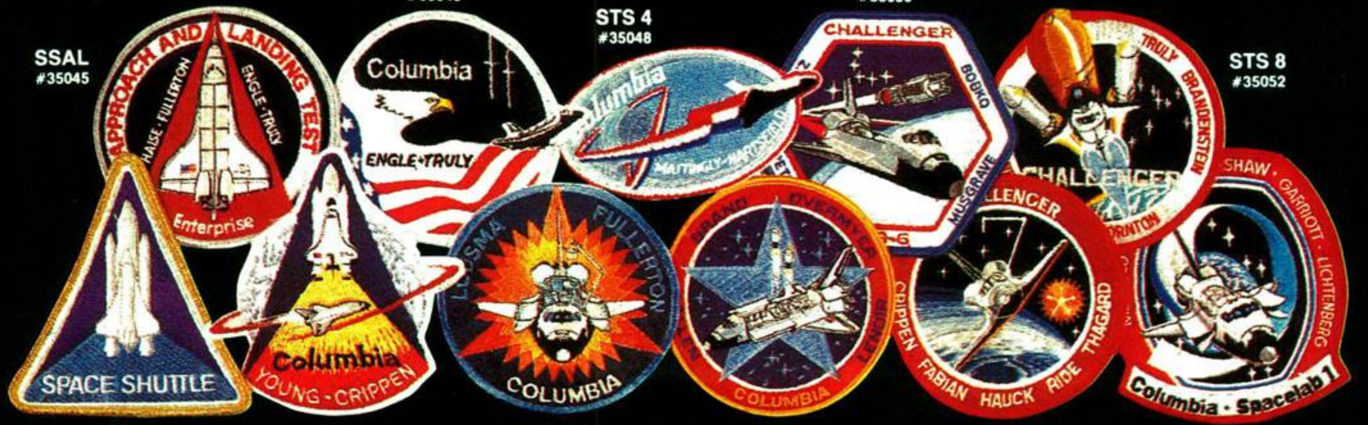
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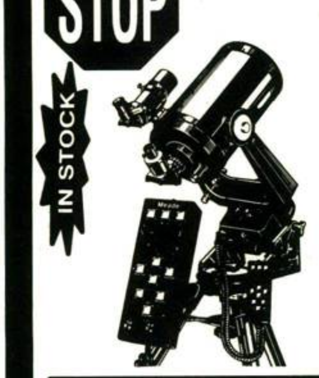

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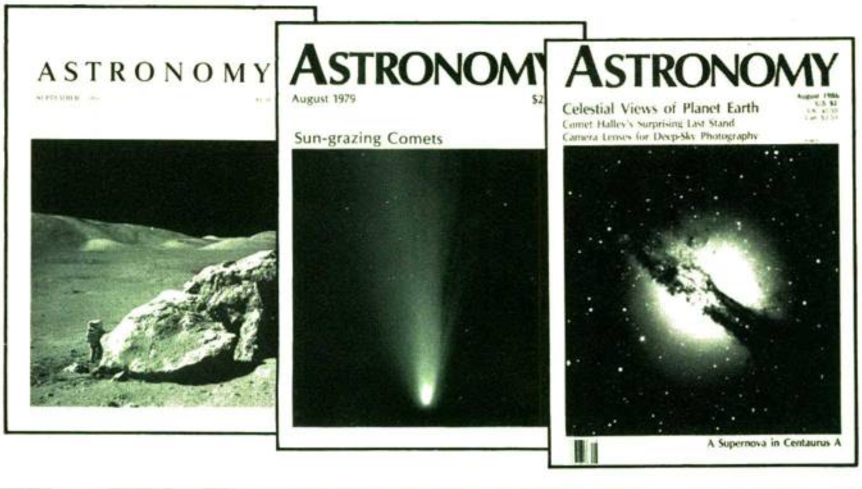
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SPECIAL SECTION

ASTRONOMY's 1989 Sky Guide

This handy reference to the night sky spotlights the year's best solar system events.

by Robert Burnham

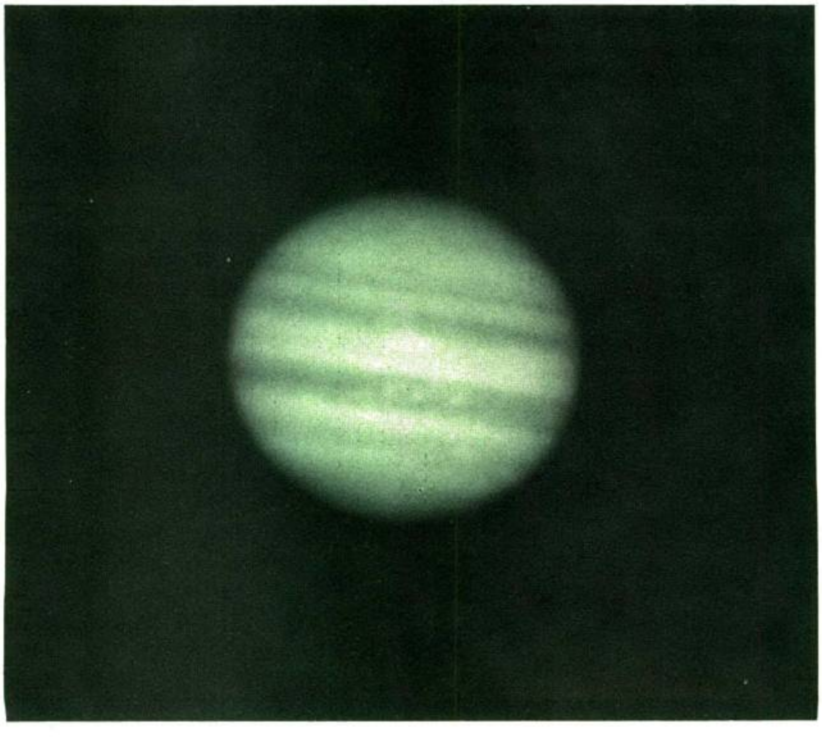
ASTRONOMY's 1989 Sky Guide gives you a look at the celestial events coming your way this year. It contains all you need to plan a great year of skywatching.

Do you want to take a vacation under dark, moonless skies? Then turn to page 88 where you'll find a chart showing the Moon's "dark times" and "bright times" for the entire year. Which are the best meteor showers in 1989? See page 87. And what about seeing Mercury? Flip to page 80 where each apparition is rated for visibility.

Unlike our Sky Almanac, which each month highlights the current celestial happenings, Sky Guide takes a yearlong look at upcoming events. It is organized by subject, starting with a "local" event — solar and lunar eclipses — and continuing through the solar system from Mercury outward.

The coming year shapes up splendidly for backyard astronomers. Mercury will put in an excellent appearance in May. All year Saturn and Neptune engage in a triple conjunction that will draw lots of attention to Neptune (due for a visit from the *Voyager* spacecraft this August.) Pluto reaches perihelion for the first time in two-and-a-half centuries and passes close to a triple star.

No matter what your observing interests — from naked-eye meteor watching to tracking Pluto with a big telescope — there's lots to see this year in the "sky-scape" overhead!



JUPITER, KING OF THE PLANETS, is an evening object this spring and a fine sight in any size telescope. Photo by Don Parker.

Eclipses

Two solar and two lunar eclipses occur this year. Both solar eclipses are partial, while both lunar ones are total. (For more about this year's lunar eclipses, see page 82.)

For viewers in North America and Hawaii, 1989's only solar eclipse will occur on March 7. The Moon crosses the northern limb of the Sun, which is traveling northeast on the ecliptic through Aquarius. At greatest eclipse, 83 percent of the Sun's diameter will be covered, but this is visible only from Alaska and northwestern Canada. As the map on page 82 shows, the farther south you go, the smaller the portion of Sun that is eclipsed. The times shown next to the cities are the local standard times of maximum eclipse. The eclipsed solar disks are oriented the way they will look when you face the Sun directly at the time shown.

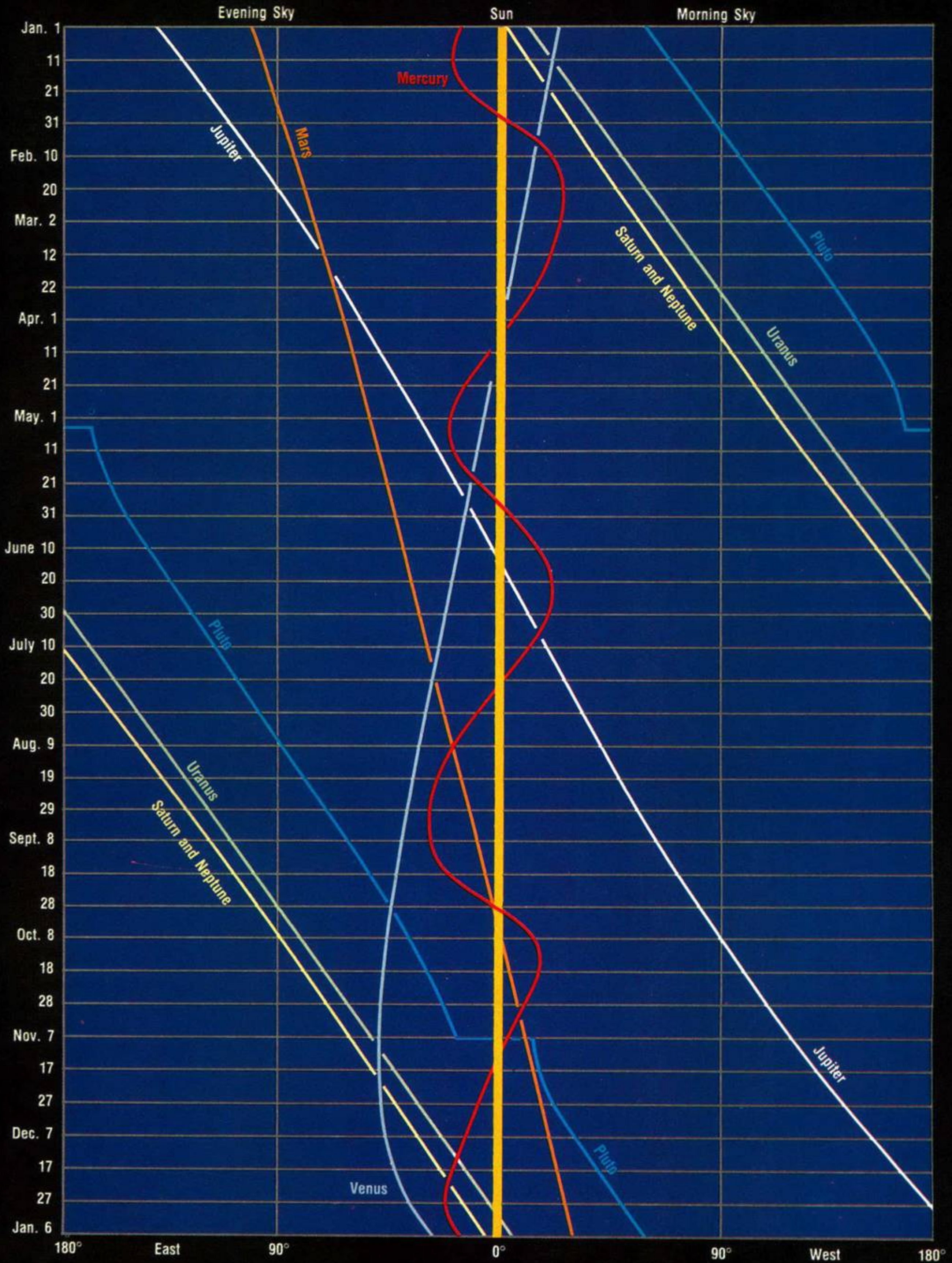
The second solar eclipse this year occurs on August 31 and is visible only from parts of Antarctica and southern Africa. At maximum eclipse, 64 percent of the Sun is covered.

Mercury

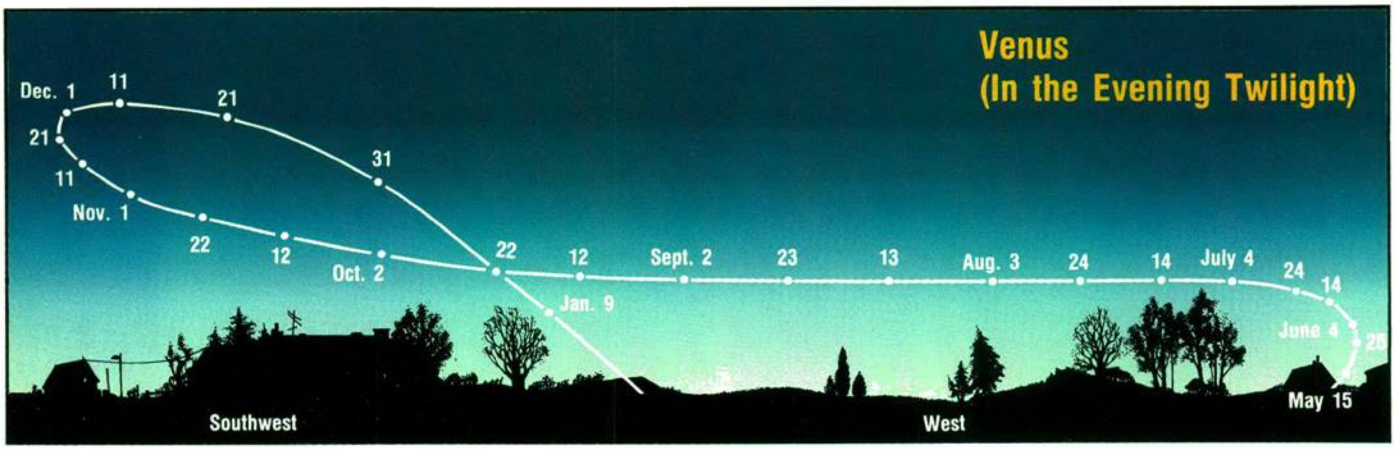
The planet orbiting closest to the Sun is notorious for being hard to see, but it can be found more easily than you think. Many people, in fact, have probably seen it low in the twilight and thought it was just another star. Mercury swings out to the east or west of the Sun seven times this year, and four of these "elongations" occur in the evening sky.

After sunset on **January 9**, the date of elongation, Mercury will be visible at magnitude −0.6 low in the southwestern sky. In a telescope its diameter will be 6.8″. Mercury lies among the stars of Capricornus, though these will be hard to see in the twilight. Mercury is about 7° high, forty-five

Elongations of the Planets



Planets that lie east of the Sun are visible in the evening sky after sunset; those to the west of the Sun are visible in the morning sky before sunrise. Opposition occurs when a planet has an elongation of 180°; the planet is then highest at midnight. (Pluto's path differs markedly from the others because it lies about 17° away from the ecliptic.)



minutes after sunset, and a skinny crescent Moon will lie to its upper left.

After a week or so Mercury will slip back down toward the sunset point and vanish from view. It passes between Earth and the Sun on January 25 and soon after begins to rise in the southeast just before the Sun. Peak elevation on **February 18** is lower than in January, which makes Mercury more difficult to spot. At 0.1 magnitude, 6.9" Mercury is still in Capricornus, but on these mornings the stars of the Teapot in Sagittarius (with bright Saturn nearby) are more conspicuous, lying off to the right.

May 1 is the best day of the year to see Mercury, and it's also the year's most dramatic apparition for the planet. Visible about 10° high in the west-northwest after sunset, 0.3-magnitude Mercury will lie to the left of the Pleiades cluster in Taurus with −2.0-magnitude Jupiter and the Hyades cluster to its upper left — a striking sight for the naked eye, binoculars, or camera. (Mercury's diameter will be 7.9".) All in all, at this apparition Mercury will be in view from mid-April to mid-May — don't miss it!

In the morning elongation that follows on **June 18**, Mercury is lower and less prominent; at magnitude 0.6 and 8.2" across, it will be rising in the east-northeast right below the Pleiades. The next elongation, an evening one on **August 29**, is the worst of the year. Only a gleaming −4.0-magnitude Venus (to Mercury's upper left) will point the way down to 0.2-magnitude Mercury, 8.3" across and only a degree above the western horizon.

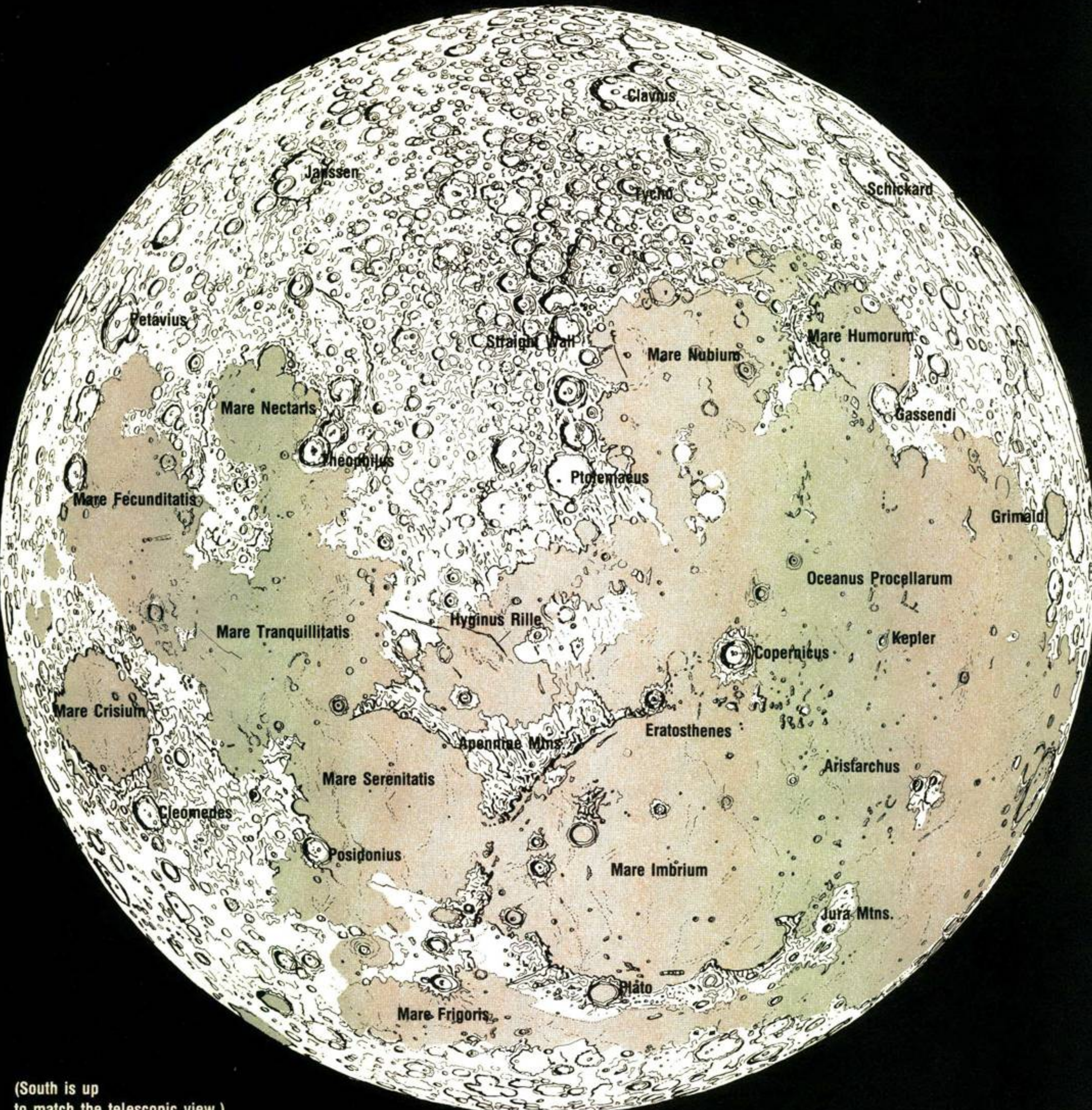
After it passes between Earth and the Sun on September 24, Mercury rises under the tail of Leo in early October before the Sun; it reaches an excellent morning elongation at mag-

Seeing Mercury in 1989

Date of Elongation	Time of Day	Chances of Seeing It
January 9	Evening	Good
February 18	Morning	So-So
May 1	Evening	Year's Best
June 18	Morning	So-So
August 29	Evening	Year's Worst
October 10	Morning	Excellent
December 23	Evening	Good

Mercury is usually visible at a low elevation for about two weeks before and after elongations that are rated "good" or better.

OFTEN HARD TO FIND, Mercury (upper right) was caught by Mace Hooley in April 1977. This May you get your best chance all year to see this elusive planet.


Clavius
Janssen
Tycho
Schickard
Petavius
Straight Wall
Mare Nubium
Mare Humorum
Mare Nectaris
Gassendi
Theophilus
Ptolemaeus
Mare Fecunditatis
Grimaldi
Oceanus Procellarum
Hyginus Rille
Mare Tranquillitatis
Kepler
Copernicus
Mare Crisium
Eratosthenes
Apennine Mtns.
Aristarchus
Mare Serenitatis
Cleomedes
Posidonius
Mare Imbrium
Jura Mtns.
Plato
Mare Frigoris

(South is up
to match the telescopic view.)

Exploring the Moon by Telescope

Lunar surface features look best when the sunlight hits them at a low angle, so the prime time for Moon-watching is when the Moon is approximately 3 days to 13 days old and from 16 days to 26 days old. As you explore the line between lunar night and day (called the terminator), watch how craters and mountain ranges change as the lunar day progresses.

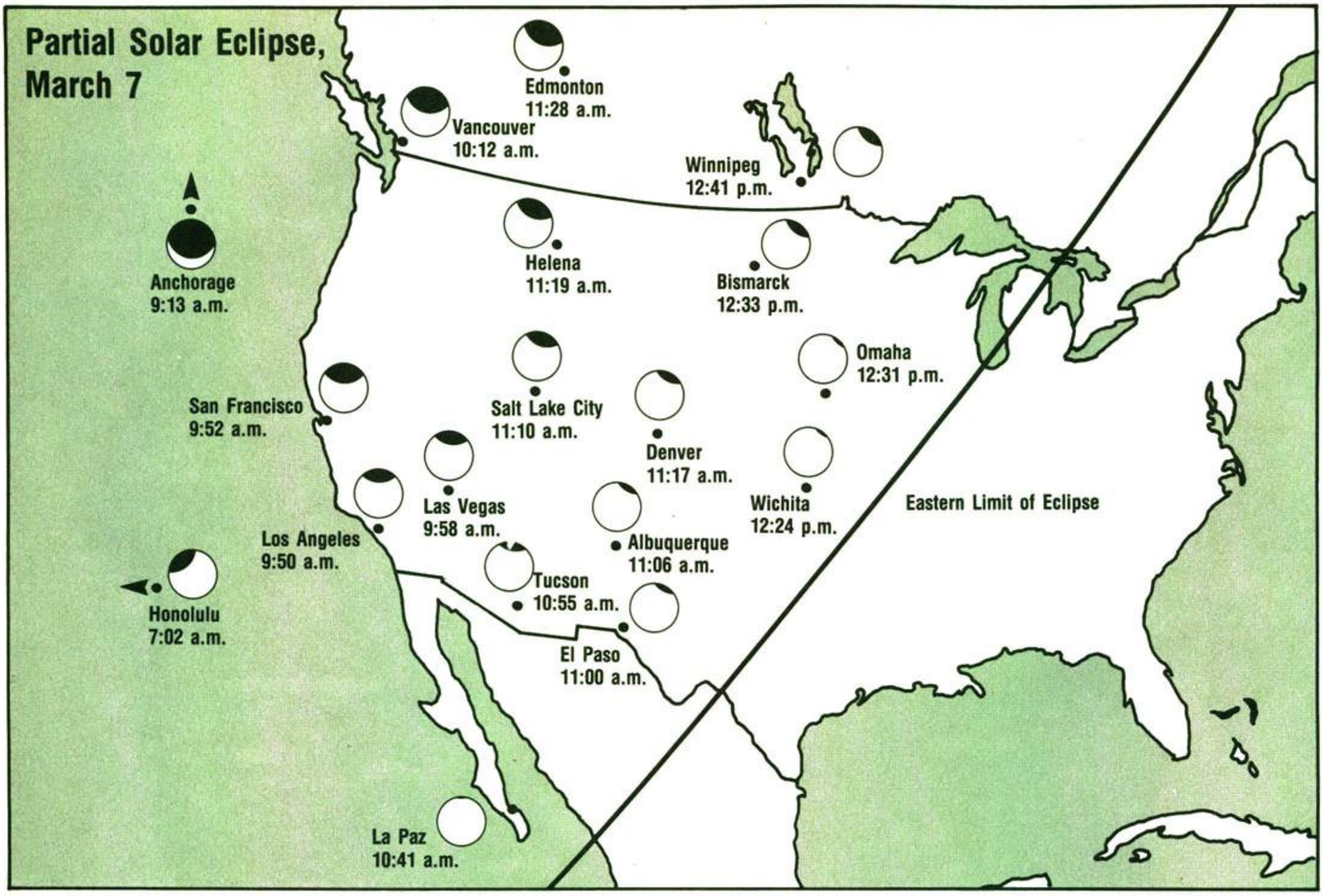
At sunrise a crater may be just a ring of light around a dark interior. When the Sun rises higher, landslides and terraces become visible on the crater's inner walls. At Full Moon the crater flattens as shadows disappear. Then the lengthening afternoon shadows start to pick out features again until the pools of black merge to fill in the crater.

Mountains first show as isolated "islands" of light standing on the night-side of the sunrise line. These islands steadily grow and join as the rising Sun's rays crawl down the mountains' eastern face into the foothills.

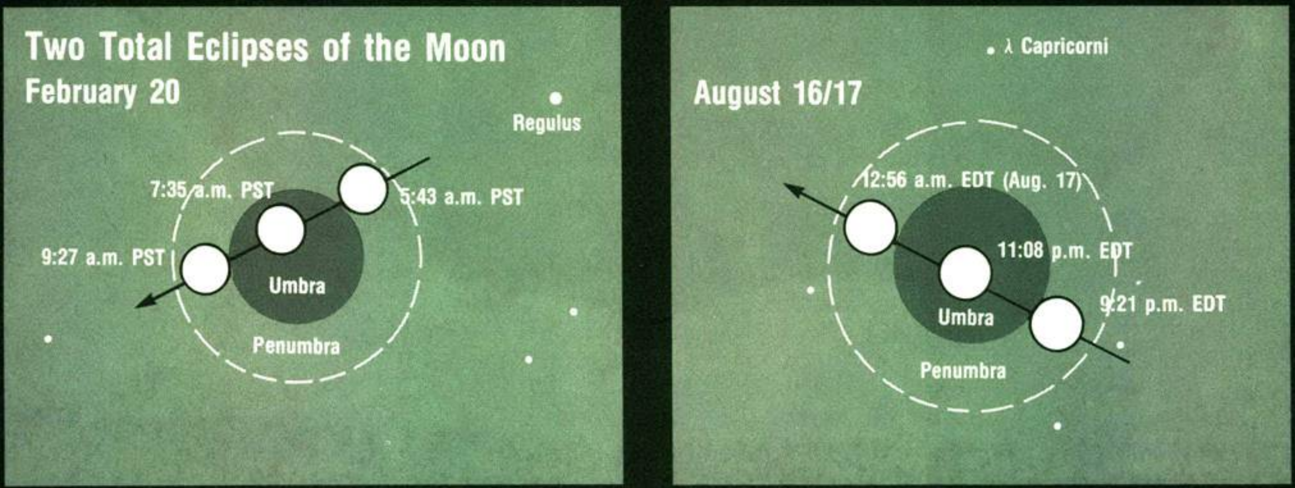
The smooth dark plains called "seas" (*Mare*, MAH-ray) experience daily changes as well. Grazing light reveals long, ropy welts called wrinkle ridges where basalt has been squeezed up by volcanic or tectonic forces. You can also see dark clefts called rilles where the surface has been pulled apart.

Even Full Moon has its appeal, because there's no better time to trace the intricate patterns of bright rays. These immense splash patterns of fused and powdered rock surround a few of the Moon's newer impact craters: Tycho, Copernicus, Kepler, and Aristarchus.

Partial Solar Eclipse, March 7


Edmonton
11:28 a.m.
Vancouver
10:12 a.m.
Winnipeg
12:41 p.m.
Anchorage
9:13 a.m.
Helena
11:19 a.m.
Bismarck
12:33 p.m.
Omaha
12:31 p.m.
San Francisco
9:52 a.m.
Salt Lake City
11:10 a.m.
Denver
11:17 a.m.
Las Vegas
9:58 a.m.
Wichita
12:24 p.m.
Eastern Limit of Eclipse
Los Angeles
9:50 a.m.
Albuquerque
11:06 a.m.
Tucson
10:55 a.m.
Honolulu
7:02 a.m.
El Paso
11:00 a.m.
La Paz
10:41 a.m.

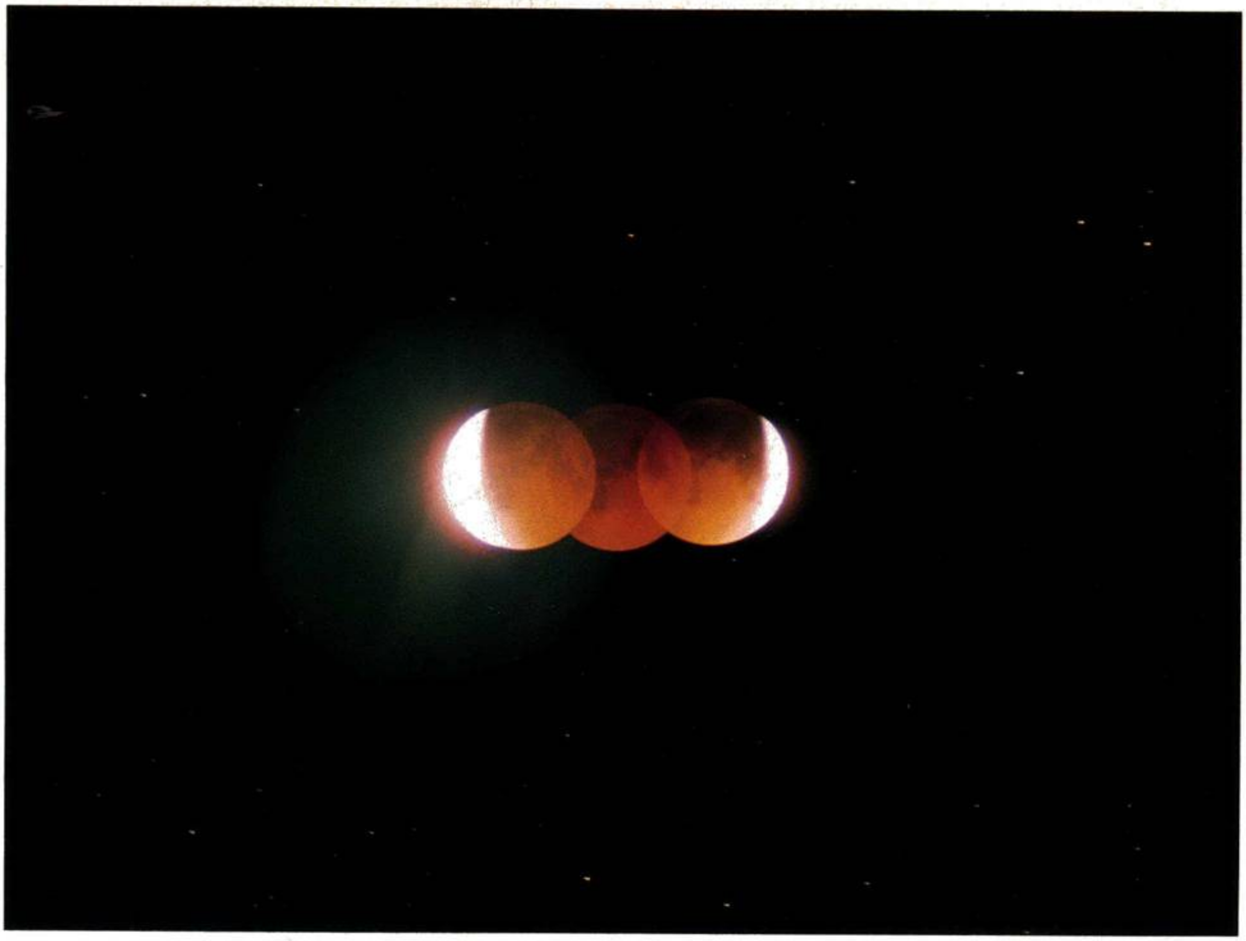
Two Total Eclipses of the Moon


February 20
Regulus
7:35 a.m. PST
5:43 a.m. PST
9:27 a.m. PST
Umbra
Penumbra
August 16/17
λ Capricorni
12:56 a.m. EDT (Aug. 17)
11:08 p.m. EDT
9:21 p.m. EDT
Umbra
Penumbra

Both of 1989's lunar eclipses are total. For North American observers the February 20 eclipse occurs at or near moonset with the Moon close to Regulus in Leo. The entry of the Moon into the umbra, the darkest part of Earth's shadow, is visible generally from the 100th meridian westward. The entire total phase, however, can be seen only from the Pacific Northwest and westward. From Hawaii, totality occurs high in the western sky only a few hours after the Moon has occulted Regulus (at 10h10m UT, 12:10 a.m. Hawaii time).

On August 16, viewers in the eastern half of the continent will see the Full Moon rise and then enter eclipse. West of the 95th meridian, the Moon will rise at least partially in the umbra and west of 130° west, moonrise occurs after totality is over. (The eclipse is invisible from Hawaii and Alaska.) Alaska.)

The penumbral phases dim the Moon too little to be detected by eye, but the entry of the umbra onto the lunar disk is unmistakable. With the Moon partway into the umbra, the eclipsed portion looks dark, dusty gray. Fully into the umbra, however, the Moon's disk displays a coppery color caused by sunlight refracting through Earth's atmosphere. How dark and how red an eclipse will be is a favorite guessing game of Moon-watchers! Both of this year's eclipses go deep in the umbra, so the Moon may become quite dark.



nitude −0.4 and 7.0″ diameter on **October 10**. Look for it about 8° high in the east as morning twilight begins to brighten swiftly.

Mercury's last appearance of the year comes in the evening sky as 1989 draws to a finish. **December 23** is the date of elongation, when −0.3-magnitude Mercury will lie above and to the left of 0.5-magnitude Saturn in the southwest. It will be 6.6″ across.

Most backyard astronomers find that locating Mercury is a lot easier if they scan the right area of sky with binoculars. Focus first on a distant building or trees and then sweep the sky from side to side, starting at the horizon and working upward. Look for an amber-white "star" low in the twilight. Once you locate it with binoculars, seeing it naked eye is usually easy.

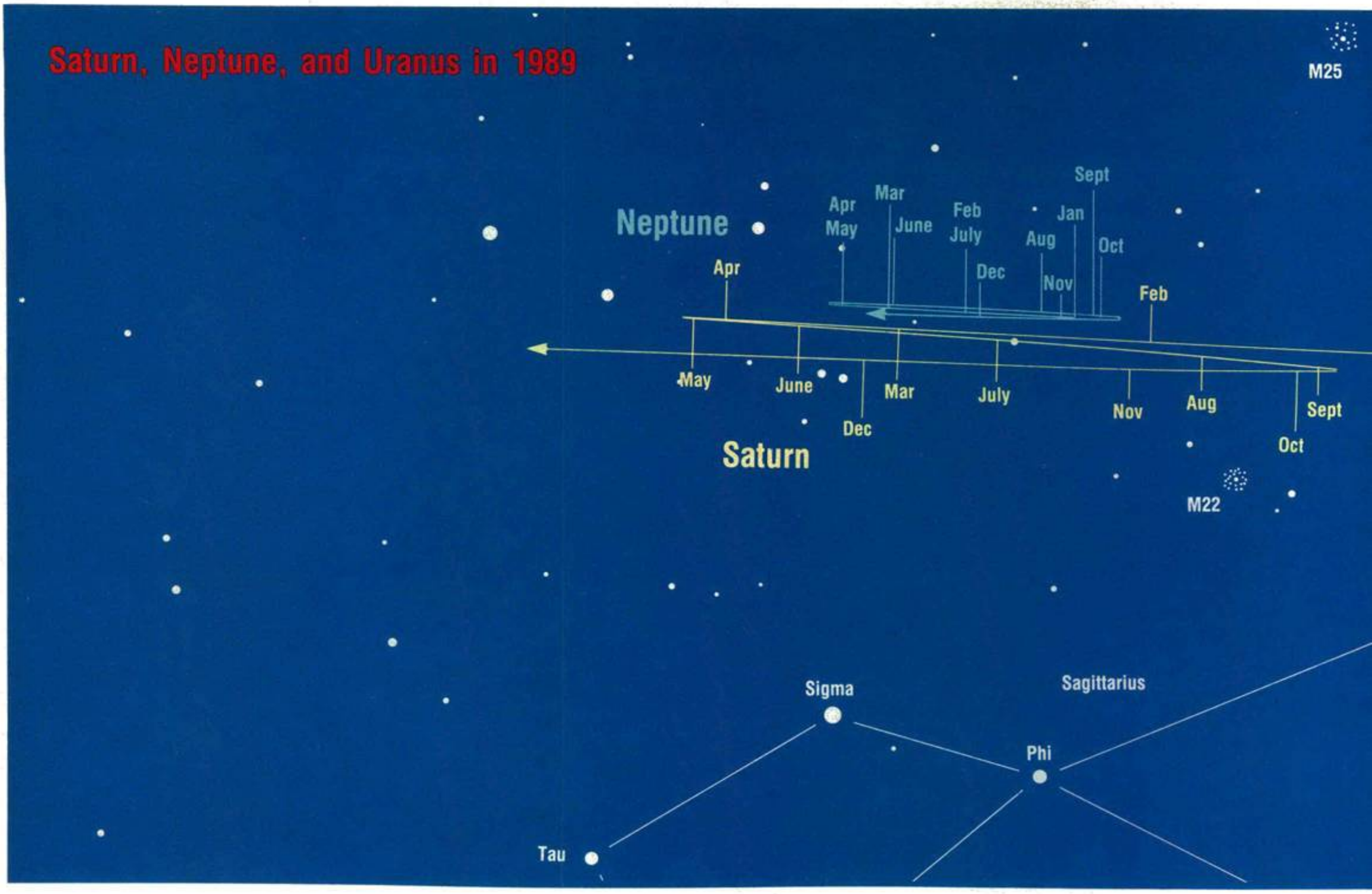
Getting a clear view of Mercury in a telescope can be challenging, thanks to Mercury's low elevation. In the evening, try to locate the planet before the sky becomes very dark so you can see it at a higher elevation with less atmospheric distortion. In a morning elongation, keep observing the planet after sunrise, provided the seeing remains steady.

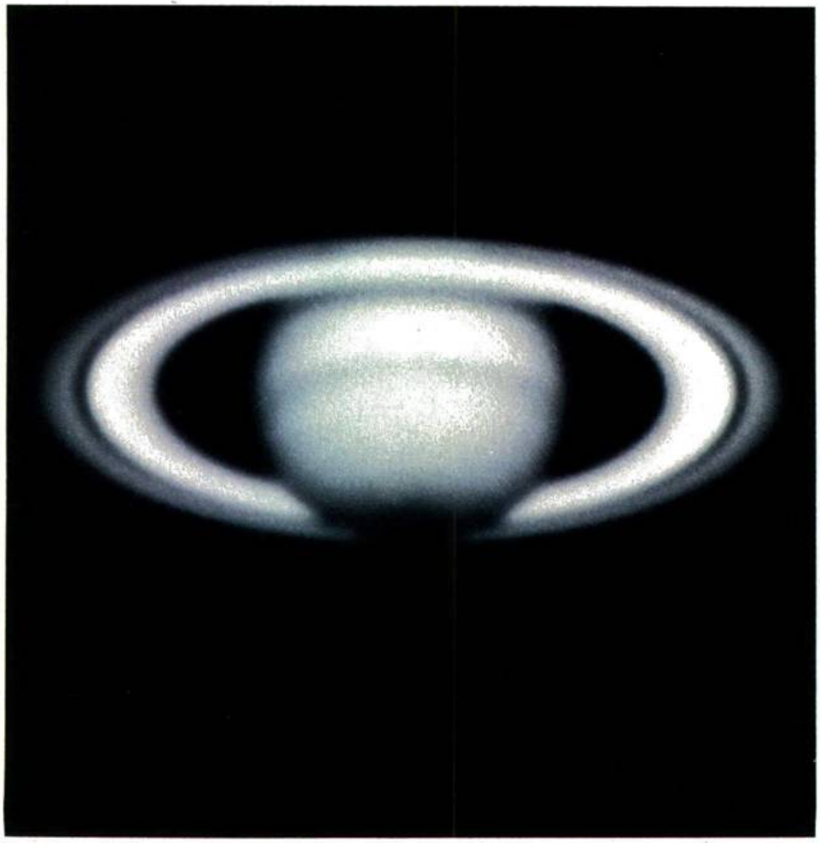
Venus

As 1989 opens, Venus is visible at

A COPPER MOON FLOATS through eclipse in Ronald Royer's triple-exposure photo taken July 6, 1982. He produced this photo by guiding his telescope on the stars.

A PARTIALLY ECLIPSED SUN shines through broken clouds on October 3, 1986, at Cody, Wyoming, where the eclipse was 26 percent total. Photo by Dewey Vanderhoff.


Saturn, Neptune, and Uranus in 1989



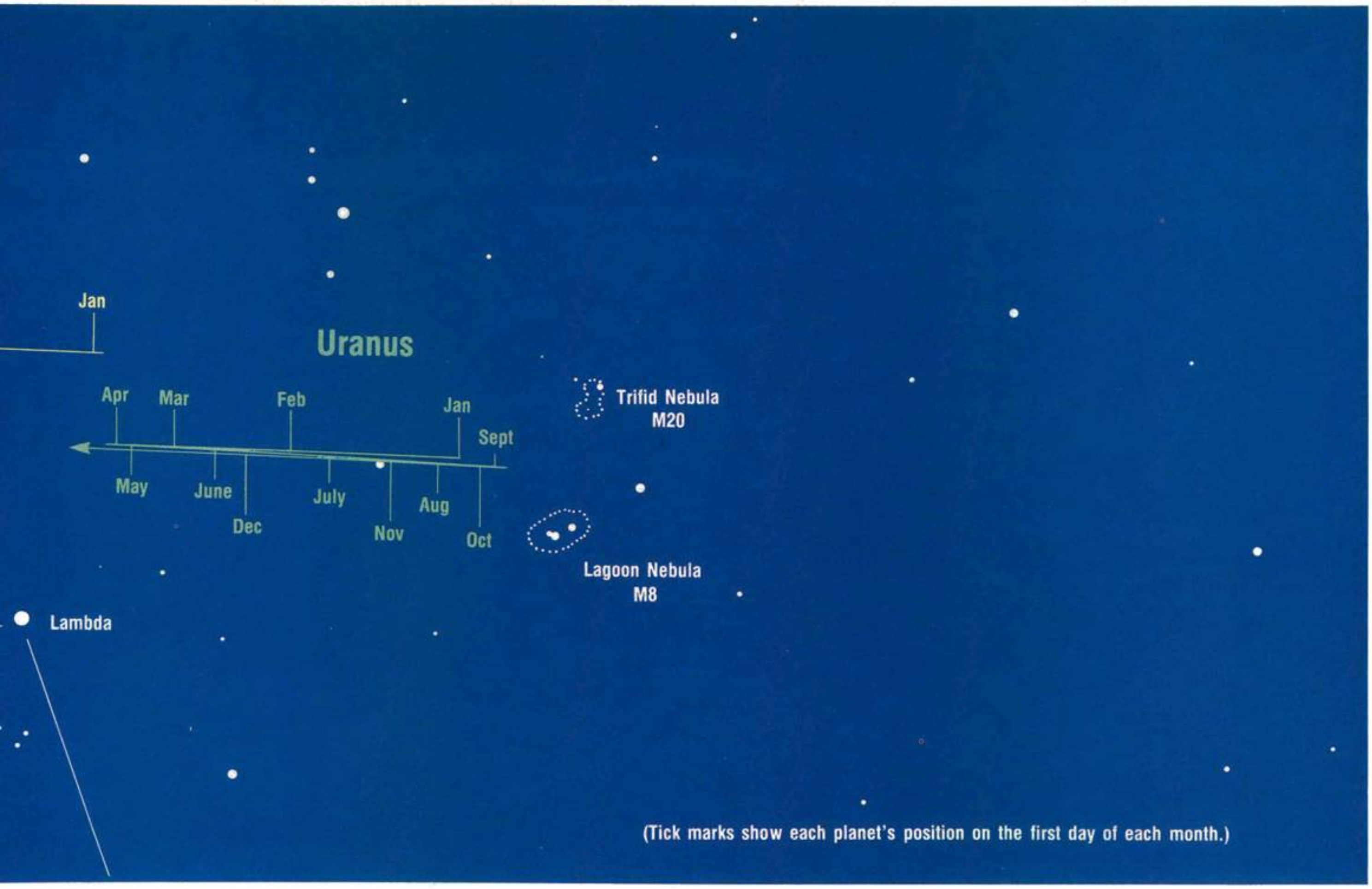
SATURN'S RINGS TIP more fully toward us this year than they will until early next century. Photo by Jean Bourgeois.

magnitude −3.9 very low in the eastern sky just before sunrise. In a telescope its disk is about 11″ across. By the end of January, however, Venus is all but swallowed up by the glare of the Sun. On April 4, it passes superior conjunction and shifts into the evening sky. The chart on page 80 shows its track in the western sky, forty-five minutes after sunset.

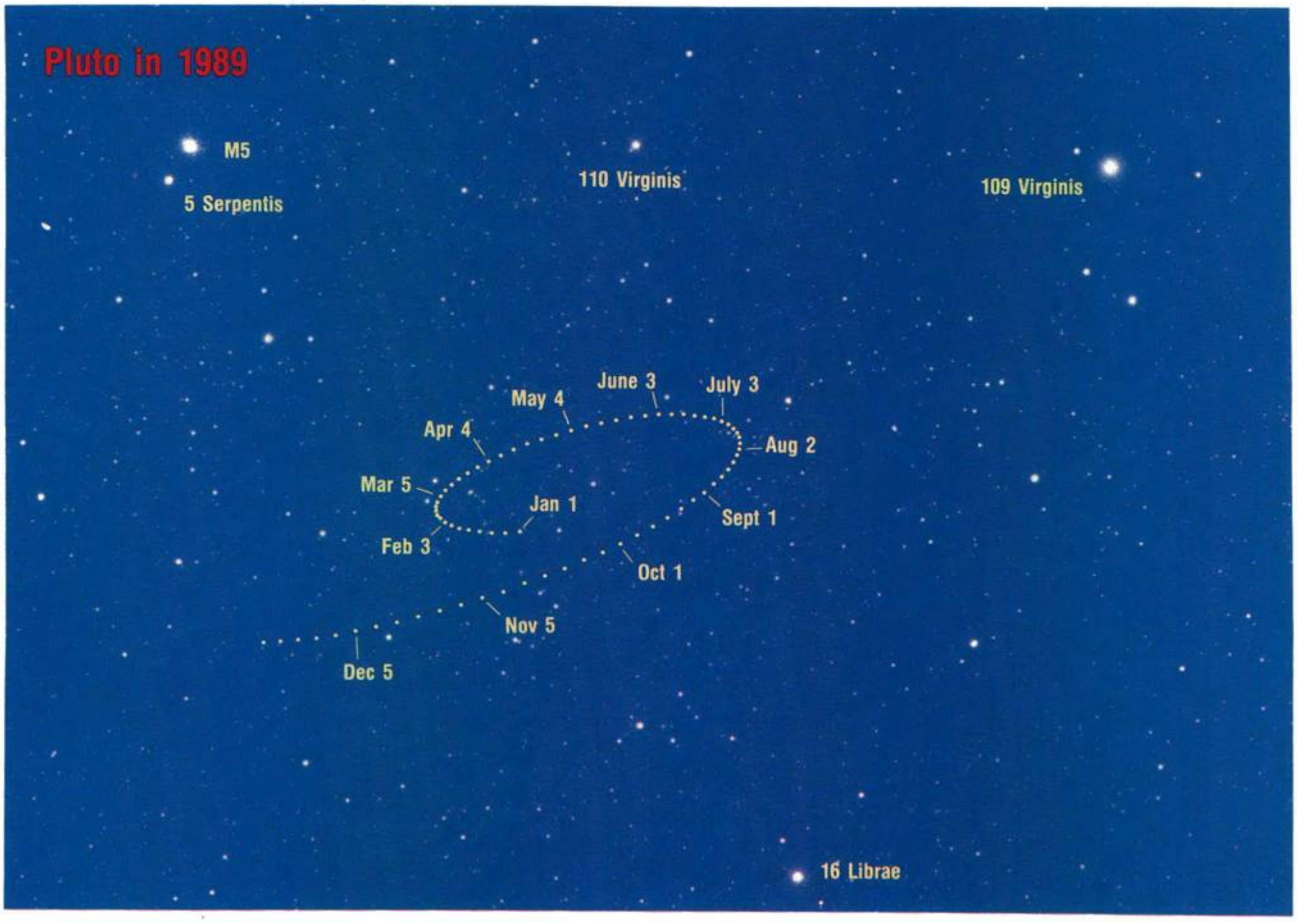
While this apparition does not reach high elevations, Venus' great brilliance (−4 magnitude on average) makes it very prominent. This bright planet will be an eye-catching feature of every clear evening till the end of the year.

Greatest elongation is on November 8, but best visibility and highest elevation (20°, forty-five minutes after sunset) come a month later. Traditionally, viewing Venus by telescope is most exciting for backyard astronomers during this "dive to the Sun" in the last weeks of an evening elongation. This is when the planet's appearance changes almost nightly and its crescent grows extremely thin and nearly big enough (50″) to see with the naked eye.

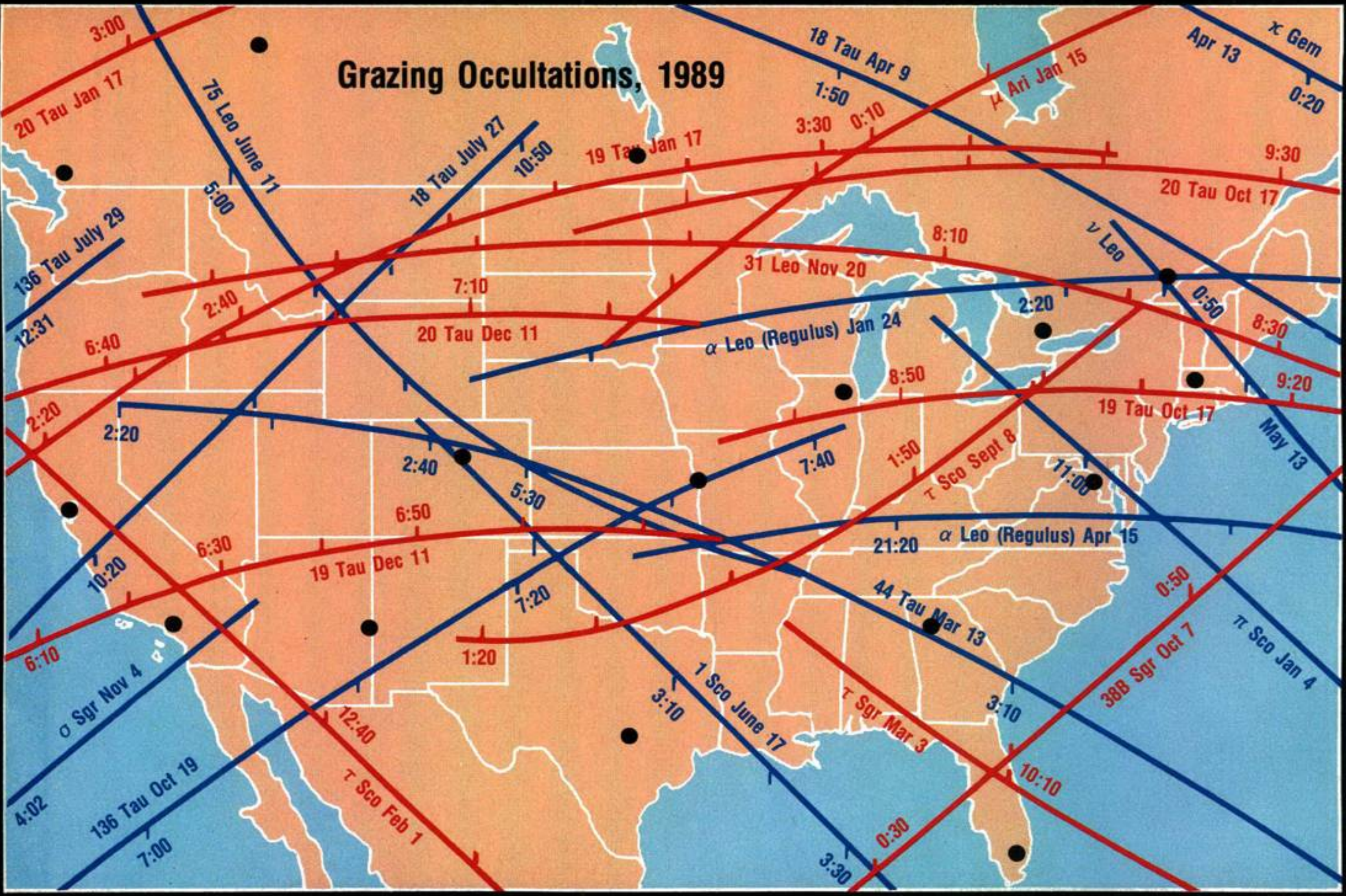
Because Venus is so bright, many observers prefer to view it during partial daylight. This reduces the contrast between the bright planet and the sky around it, which lets you see the disk


Jan
Uranus
Apr
Mar
Feb
Jan
Sept
May
June
Dec
July
Nov
Aug
Oct
Trifid Nebula
M20
Lagoon Nebula
M8
Lambda

(Tick marks show each planet's position on the first day of each month.)


Pluto in 1989

M5
5 Serpentis
110 Virginis
109 Virginis
June 3
July 3
May 4
Apr 4
Aug 2
Mar 5
Jan 1
Sept 1
Feb 3
Oct 1
Nov 5
Dec 5
16 Librae


Grazing Occultations, 1989
20 Tau Jan 17
3:00
75 Leo June 11
5:00
18 Tau July 27
10:50
19 Tau Jan 17
18 Tau Apr 9
1:50
3:30
0:10
μ Ari Jan 15
Apr 13
x Gem
0:20
9:30
20 Tau Oct 17
136 Tau July 29
12:31
2:40
7:10
20 Tau Dec 11
31 Leo Nov 20
8:10
ν Leo
0:50
8:30
6:40
2:20
2:20
α Leo (Regulus) Jan 24
2:20
8:50
9:20
19 Tau Oct 17
May 13
2:40
5:30
7:40
1:50
τ Sco Sept 8
11:00
6:50
21:20
α Leo (Regulus) Apr 15
6:30
19 Tau Dec 11
10:20
7:20
44 Tau Mar 13
0:50
6:10
1:20
π Sco Jan 4
σ Sgr Nov 4
3:10
1 Sco June 17
τ Sgr Mar 3
388 Sgr Oct 7
3:10
12:40
136 Tau Oct 19
4:02
τ Sco Feb 1
10:10
7:00
0:30
3:30

The map shows where some of 1989's occultations can be seen. If you view from north of a red line or south of a blue one, the Moon will occult the star named. Tick marks on the lines show universal time at 10-minute intervals. Time always increases eastward.

The universal times (and dates) of disappearances and reappearances (in bold) are in the table. To convert to local standard time, subtract 5 hours for the EST, 6 CST, 7 for MST, 8 for PST. (During daylight-savings time, subtract 1 hour less in each zone.)

UT Date	Object	Mag.	Van	NCal	LA	Edm	NM	Den	Aus	Win	KC	Chi	Atl	Mia	Tor	Wash	Mont	Mass	Hal
Jan. 4	π Sco	3.0												10:19		10:51			
									11:16				**11:21**	**11:28**		**11:09**			
Jan. 17	19 Tau	4.4	2:06			2:24				3:06									
Jan. 24	α Leo	1.3										1:56	1:41	1:40	2:03	1:50	2:15	2:01	2:18
									2:38		**2:34**	**2:33**	**2:43**	**2:46**	**2:34**	**2:45**	**2:29**	**2:43**	**2:40**
Feb. 1	τ Sco	2.9					12:20	12:17	12:29	12:28	12:28	12:39	12:47	13:03	12:55	13:01	13:05	13:09	13:25
							13:08	**13:27**	**13:36**	**13:46**	**13:50**	**14:04**	**14:14**	**14:24**	**14:20**	**14:28**	**14:29**	**14:33**	**14:45**
Mar. 3	τ Sgr	3.4											**10:29**		**11:00**	**10:56**			
Apr. 9	19 Tau	4.4										1:45			1:37	1:47	1:32	1:37	1:31
	20 Tau	4.0															1:55	2:04	1:49
Apr. 12-13	x Gem	3.7												0:04				23:49	0:09
Apr. 15	α Leo	1.3											20:58	20:47					
									21:39				**21:42**	**21:58**					
June 17	ι Sco	4.8							2:45										
July 27	19 Tau	4.4	**10:55**	**10:36**	**10:28**		**10:25**	**10:40**			**10:33**								
	20 Tau	4.0	**11:02**	**10:36**															
Sept. 8	τ Sco	2.9	0:18			0:26	1:07	0:50		0:51	1:15	1:24			1:41				
			1:06			**1:27**	**1:12**	**1:40**		**1:52**	**1:55**								
Oct. 6-7	388 Sgr	4.7										23:46	0:05		0:03	0:16	0:12	0:19	
Oct. 17	19 Tau	4.4	**8:34**	**8:14**	**8:04**	**8:50**		**8:32**		**9:07**		**8:56**			**9:18**		**9:33**	**9:24**	**9:46**
	20 Tau	4.0	**8:41**			**8:59**				**9:04**									
Oct. 19	136 Tau	4.5							**7:49**				**8:17**	**8:29**		**8:26**		**8:21**	
Nov. 20	31 Leo	4.6	**8:12**			**8:23**				**8:19**							**8:35**		**9:00**
Dec. 11	19 Tau	4.4	5:50	5:54		6:06		6:33		6:29	6:55	6:55			6:59	7:12	7:01	7:07	7:09
	20 Tau	4.0	6:11			6:24				6:53					7:27		7:23	7:33	7:28

Van, Vancouver; NCal, northern California; LA, Los Angeles; Edm, Edmonton; NM-AZ, New Mexico-Arizona; Den, Denver; Aus, Austin; Win, Winnipeg; KC, Kansas City; Chi, Chicago; Atl, Atlanta; Mia, Miami; Tor, Toronto; Wash, Washington; Mont, Montreal; Mass, Massachusetts; Hal, Halifax (not shown on map).

more clearly with less interference from glare.

Mars

Nineteen eighty-nine is an "off year" for Mars, because it is wedged between two years with oppositions. Mars begins the year in Pisces in the evening sky at 0.0 magnitude and with a telescopic diameter of 9″. Then dimming and shrinking steadily, it slips rapidly eastward along the zodiac through Aries, Taurus, Gemini, Cancer, and Leo before the Sun finally catches up to it in Virgo on September 29 — a chase that traverses half the ecliptic circle! By this time Mars has faded to magnitude 1.7 and its diameter is 3.5″.

In the autumn months after solar conjunction Mars soon rises ahead of the Sun and continues its eastward drive along the zodiac, reaching into Scorpius and Ophiuchus by New Year's Day of 1990. The stage is then set for Mars' next opposition on November 27, 1990, in Taurus.

Jupiter

For roughly the first half of 1989 Jupiter will be a conspicuous feature in the evening sky, where it is conveniently placed for viewing this spring. On January 1, it has a brightness of −2.7 magnitude and an equatorial diameter of 46″.

As 1989 opens, Jupiter lies south of the Pleiades cluster in Taurus. It is by-passed on March 12 by Mars, which is moving rapidly eastward. On May 23 as Jupiter (by now very low in the northwest) is about to vanish into the twilight, it meets Venus as the latter emerges from the Sun's glare. The two will pass less than a degree apart and make an attractive sight.

Solar conjunction for Jupiter comes on June 9. When the planet becomes visible again low in the northeast around the end of June, it will be moving into Gemini where it spends the rest of the year. Opposition occurs on December 27, with Jupiter only a little past the ecliptic's northernmost point. It will be at −2.7 magnitude and have a diameter of 47″.

The Outer Gas Giants

In 1989 Saturn, Uranus, and Neptune lie north of the Teapot asterism in Sagittarius, a region of pretty star-fields and bright nebulae. All three come to opposition within a short time: Uranus (the westernmost of the three) on June 24 and both Saturn and Neptune on July 2.

The finder chart on pages 84-85 shows the top part of the Teapot and

THE WAVY TRAIL OF THIS PERSEID meteor shows that the object tumbled as it zipped into the atmosphere and burned up. Photo by Laird D. Cuthill.

1989's Major Meteor Showers

Name	Date	Hourly Rate	Prospects
Quadrantids	January 3	40-150	Excellent
Lyrids	April 22	10-15	Poor
Eta Aquarids	May 5	10-40	Excellent
S. Delta Aqr.	July 28	10-35	Poor
Perseids	August 12	40-100	So-So
Orionids	October 21	25	Poor
S. Taurids	November 3-5	10	Excellent
Leonids	November 17	5-20	Poor
Geminids	December 13	50-80	Poor

The date is that for maximum activity, but all showers listed (except the very brief Quadrantids) can be seen at diminished levels a day or two before and after the date given. Hourly rates vary depending on the shower's strength in a given year, the radiant's altitude, and how dark the skies are at your observing location. An "excellent" prospect means the Moon will not interfere during the after-midnight hours; for the Perseids the gibbous Moon sets about an hour after midnight.

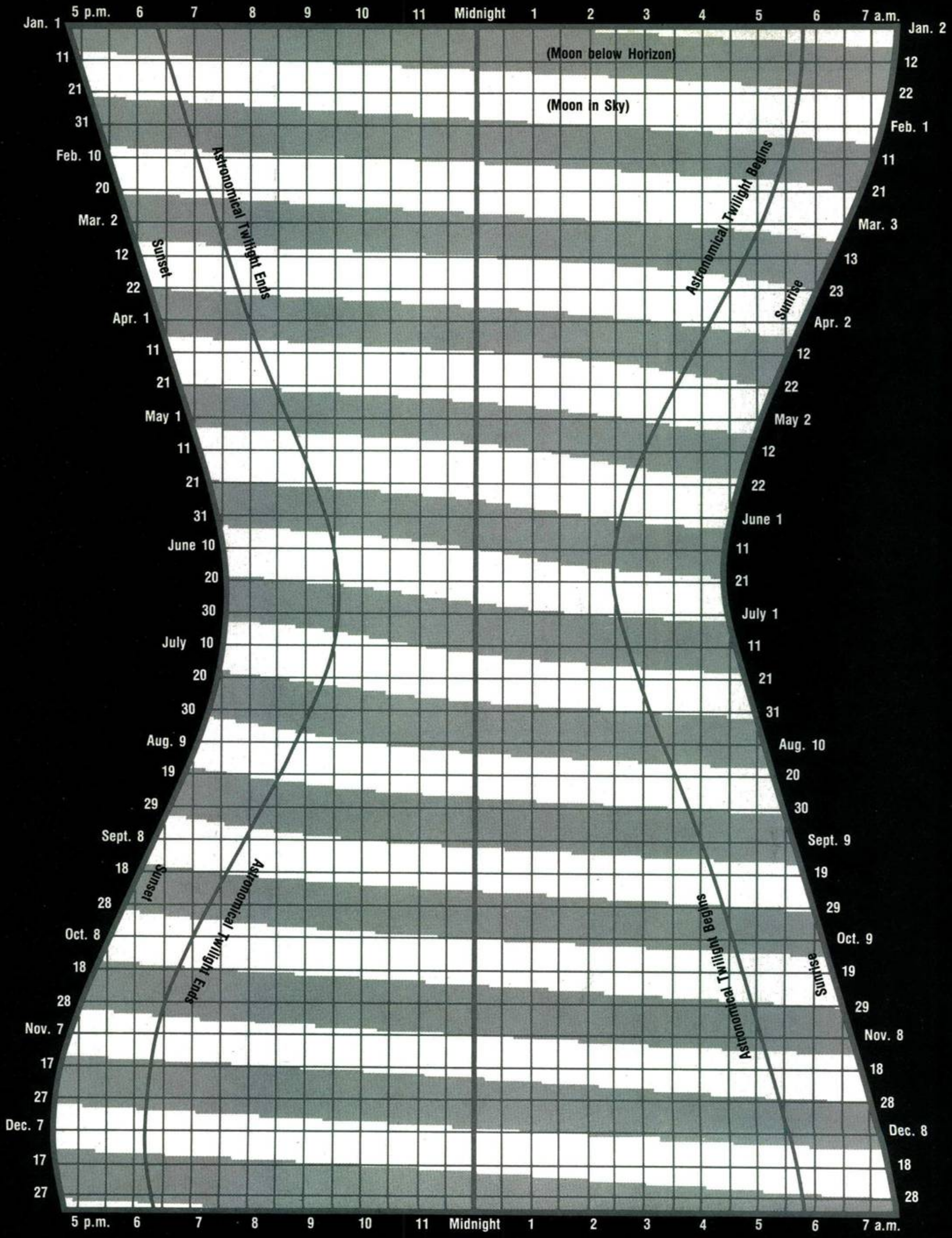
Getting Straight with the Sky

The key to learning the stars is beginning with an object you can identify. The Moon is highly visible, but a more reliable "sky mark" is a bright planet. This spring Mars and Jupiter will be prominent in the evening sky. (Both are shown on the monthly star map.)

Some moonless evening go out and face south. Hold the star map overhead. (To read it, cover your flashlight's lens with red paper.) Now look for Jupiter and Mars. When you find them (Jupiter is white, Mars amber), look at the stars nearby. Jupiter lies north of Orion, a tall hourglass figure with warm-tinted Betelgeuse and icy-white Rigel at opposite corners. Once found, Orion will lead you to other star-figures.

As weeks pass, notice how familiar stars rise earlier. Each week Orion slips farther west and new stars appear in the east. This endless parade of stars reflects the Earth's year-long circuit of the Sun. It's like seeing different parts of a forest clearing as you walk around a campfire looking outward from it.

1989's Dark Sky 'Windows'



When will the skies be dark and moonless this year? The bands of gray crossing the chart between the sunset line and the sunrise line show the dates and standard times for when the Moon will be out of the sky.

the tracks followed by the planets. Tick marks show the planets' positions on the first day of each month.

Just as with Saturn and Uranus in 1988, in 1989 Saturn and Neptune undergo a "triple conjunction." This means that an eastward-moving Saturn will pass Neptune, go on a distance, and stop. Then moving retrograde (westward), Saturn will overtake Neptune again and continue past it. West of Neptune, Saturn will stop once more and recommence direct (eastward) motion again to pass Neptune for a third time. The three dates on which Saturn lies directly south of Neptune are March 3, June 24, and November 12. (These dates are for conjunction in right ascension; when reckoned in ecliptic coordinates, the separations and times of the conjunctions change slightly.)

The first conjunction takes place when Sagittarius is rising in the morning twilight. On March 3, Saturn will lie 14′ south of Neptune. The June event promises to be the best of the three. While Saturn passes a little farther away (18′) from Neptune than it does in March, the whole Sagittarius region is prominent in the southern sky during the late evening hours. The third event, in November, is the least satisfactory. The separation is 30′ and Sagittarius is slipping from view in the evening twilight.

In June, Saturn will be 18″ across (the rings spread 42″) and shines at magnitude 0.1. Neptune is 2.3″ across and 7.9 magnitude, while Uranus is 3.8″ and 5.6 magnitude.

Pluto

A happy by-product of the deep-sky, big-telescope revolution of the past few years is that more and more backyard astronomers are equipped to see Pluto. Pluto can be seen in an 8-inch scope, but bigger apertures make things easier. And there's no better time to look for it than this year because on September 5, Pluto will be making its first perihelion since George Washington was a boy.

At magnitude 13.6, Pluto spends the whole year near the area where Virgo, Libra, and Serpens Caput join. (See the photo map on page 85.) Pluto's retrograde loop lies about 2° south of a small field of galaxies, part of the vast Coma-Virgo cluster.

About a month after opposition (May 4), Pluto will pass a couple of arcminutes due south of YBS 5594, a 5.7-magnitude star listed in the Yale *Bright Star Catalogue*. We will provide a detailed finder chart this spring so you can find this mysterious and intriguing planet. ☐

COMET BRORSEN-METCALF IS COMING late this summer, when it may resemble Comet Bradfield (in photo). Photo by Lee C. Coombs.

Comet Brorsen-Metcalf: 1989's Best?

While a bright comet might appear anytime, the best *predictable* comet this year will be Comet Brorsen-Metcalf (1847 V), which is making only its third known appearance and its first predicted one. It should be brightest in the latter half of September when it may reach a total brightness of 5th to 6th magnitude.

The comet was discovered by T. Brorsen in Germany in July 1847 and reached 7th magnitude in September of that year. In August 1919 Joel Metcalf in the United States found a comet that developed a tail a degree and a half long in September and reached 5th magnitude in mid-October. Orbital calculations soon showed the comet had a Halleylike orbit that was very close to that of Comet Brorsen.

Predictions for this year's return of Comet Brorsen-Metcalf (as it is now known) are based on only these two previous apparitions. Therefore, it is likely that the predictions will be slightly off, but by how much is anyone's guess. This summer we will provide more information on viewing the comet as it comes into view.

Starting in June at 14th magnitude, the comet, visible in the after-midnight hours, will move northeast out of Aquarius into western Pisces. It passes east of Algenib (Gamma [γ] Pegasi) around July 23 (magnitude 11.8) and lies close to the big spiral galaxy M33 in Triangulum around August 7 (9.7). Slipping between Gamma (γ) Andromedae and Algol in Perseus around August 14 (8.7), the comet heads toward northern Auriga where it passes about 5° north of Capella on August 22 (7.7). At this point the comet is as close to Earth as it comes — about 0.4 astronomical unit.

In September the comet sweeps southeast down through Lynx and Leo Minor into Leo itself. There it peaks in brightness at roughly 6th magnitude east of the Sickle in Leo about September 26. At this point the comet is rising just before morning twilight begins. Thereafter the comet will fade swiftly: it is 8th magnitude on October 15, 12th on November 15, and 15th on December 15.

Secrets of City Astrophotography

With the right filters and the new fast films you can take impressive astrophotos from the city.

by Klaus Brasch

Any astrophotographer who lives near a city knows all too well what bright skies and extensive light pollution do to pictures of deep-sky objects. During every exposure the bright sky background quickly floods into the picture and washes out the object. The result? That glorious red nebula — and everything else in the frame — develops a fatal case of the yellow-green blahs.

But what if you could somehow block the "bad" light from the sky while letting "good" light from the object reach the film? Well, you say, that sure sounds great, but how do I do it?

The trick lies in combining the right filter and the right film. For years now visual observers have been using light-pollution and other special filters to help themselves see more at the eyepiece. Yet, until very fast color films (ISO 1600+) arrived recently, it wasn't practical for deep-sky astrophotographers to shoot filtered sky pictures from urban locations.

Why not? The exposures ran too long. A good light-pollution filter takes away a lot of light and what gets through to the film doesn't amount to much. Besides often having golf-ball grain, the older emulsions, fast as they were, just weren't quite fast enough to be coupled easily with a good filter.

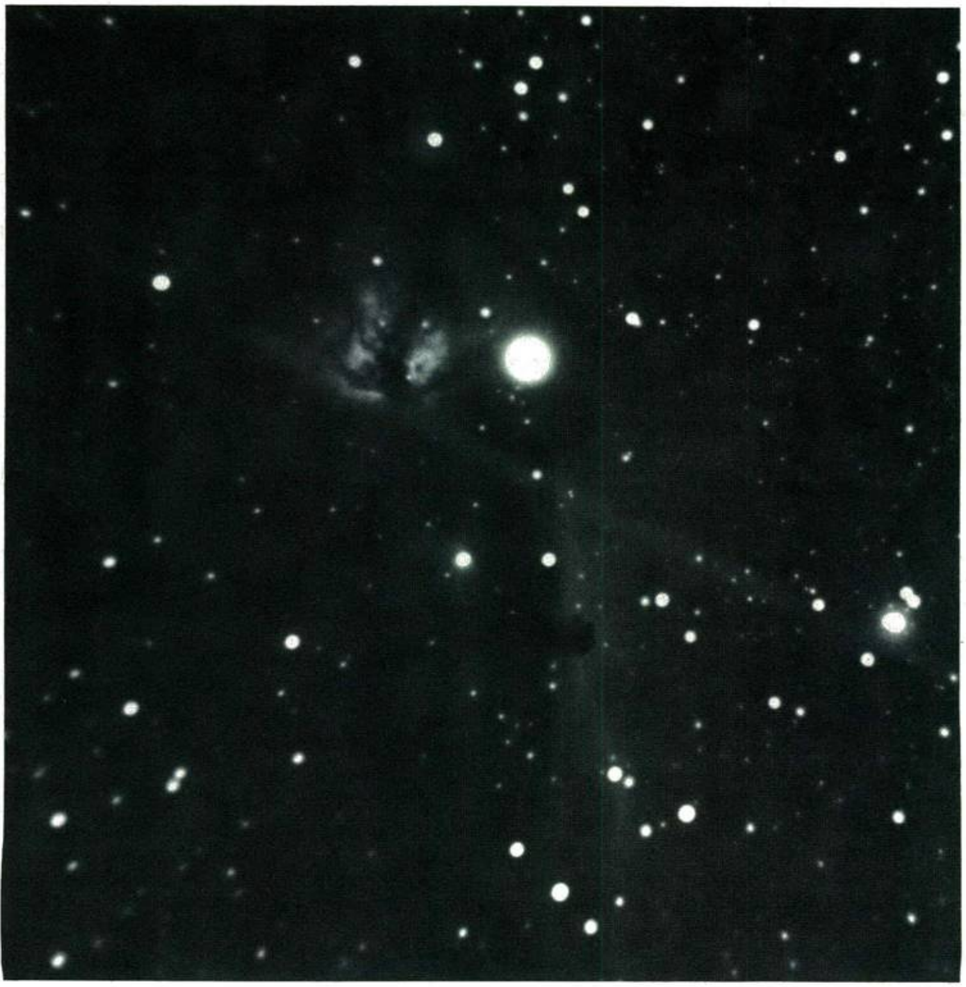
All that has changed. These new, super-fast color emulsions are *exciting*. I've worked with Ektachrome 400 and P800/1600 slide films, 3M 1000, and the Konica 1600 and 3200 print films. It is clear that Konica 3200 and Ektachrome P800/1600 are the two best films to use. Fortunately they are available in major cities and by mail order from astronomy and telescope stores.

These films can be processed commercially or at home and, unhypersensitized, have long shelf lives. They are exceptionally good with telescopes that have "slow" (high) effective f/ratios (in the f/8 to f/15 range) and long focal lengths. The popular Schmidt-Cassegrain and Maksutov telescopes fall into this category, as do most traditional refractors.

Go for a *Slow* Focal Ratio

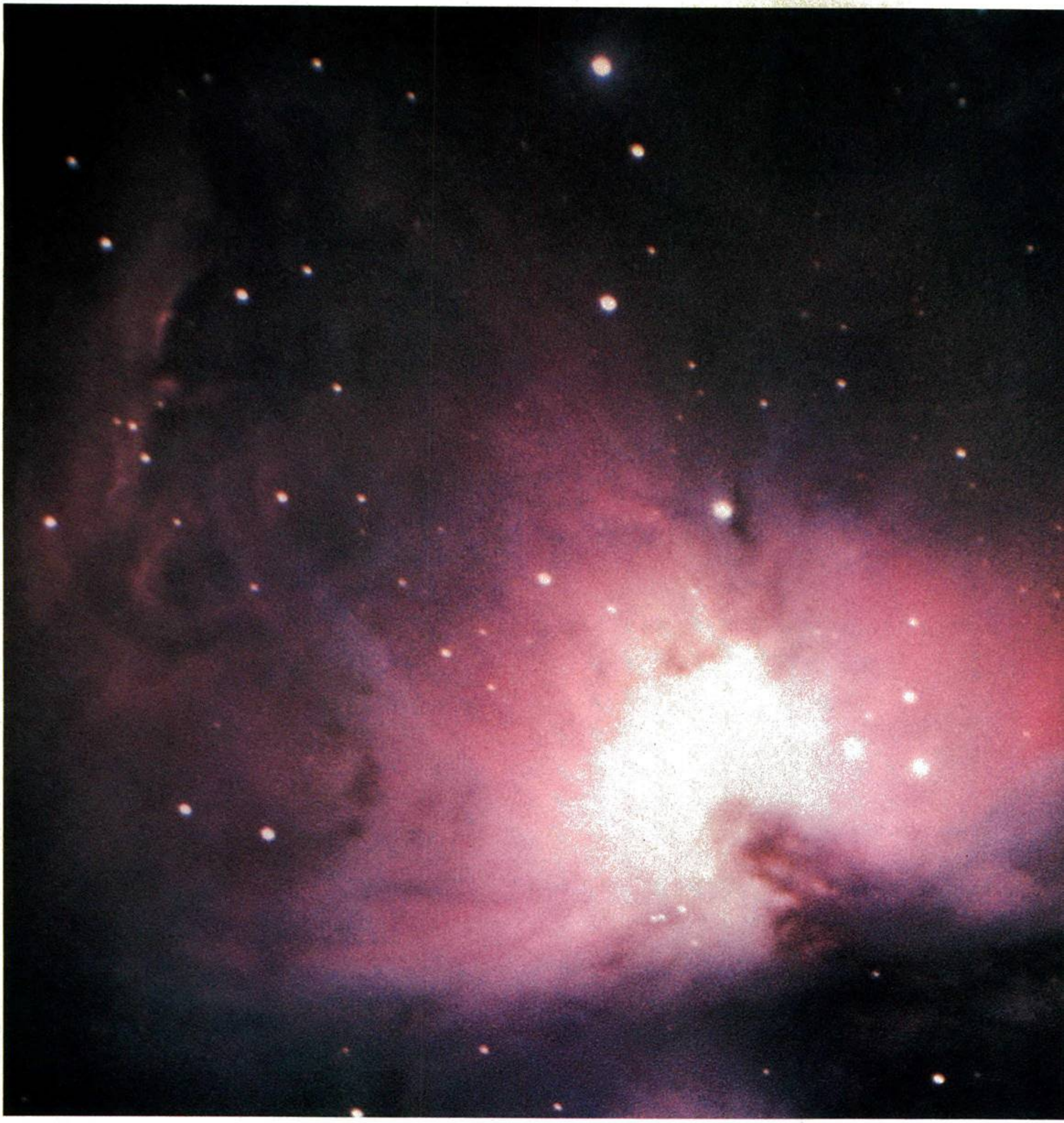
Long focal length? *Slow* f/ratio? Yes, indeed. When you take filtered astrophotos, you can use a feature of SCTs and refractors that is normally considered a disadvantage.

While any urban astrophotographer



A DEEP-SKY FILTER pulled the nebulae near Zeta Orionis out of a light-polluted sky in this 18-minute exposure on hypered Tech Pan with an 80mm f/6 lens. (All photos by the author.)

SUPER-FAST KONICA 3200, a Deep Sky filter, and a 30-minute exposure with a 14-inch SCT at f/7 produced a stunning picture of the Omega Nebula, M17.

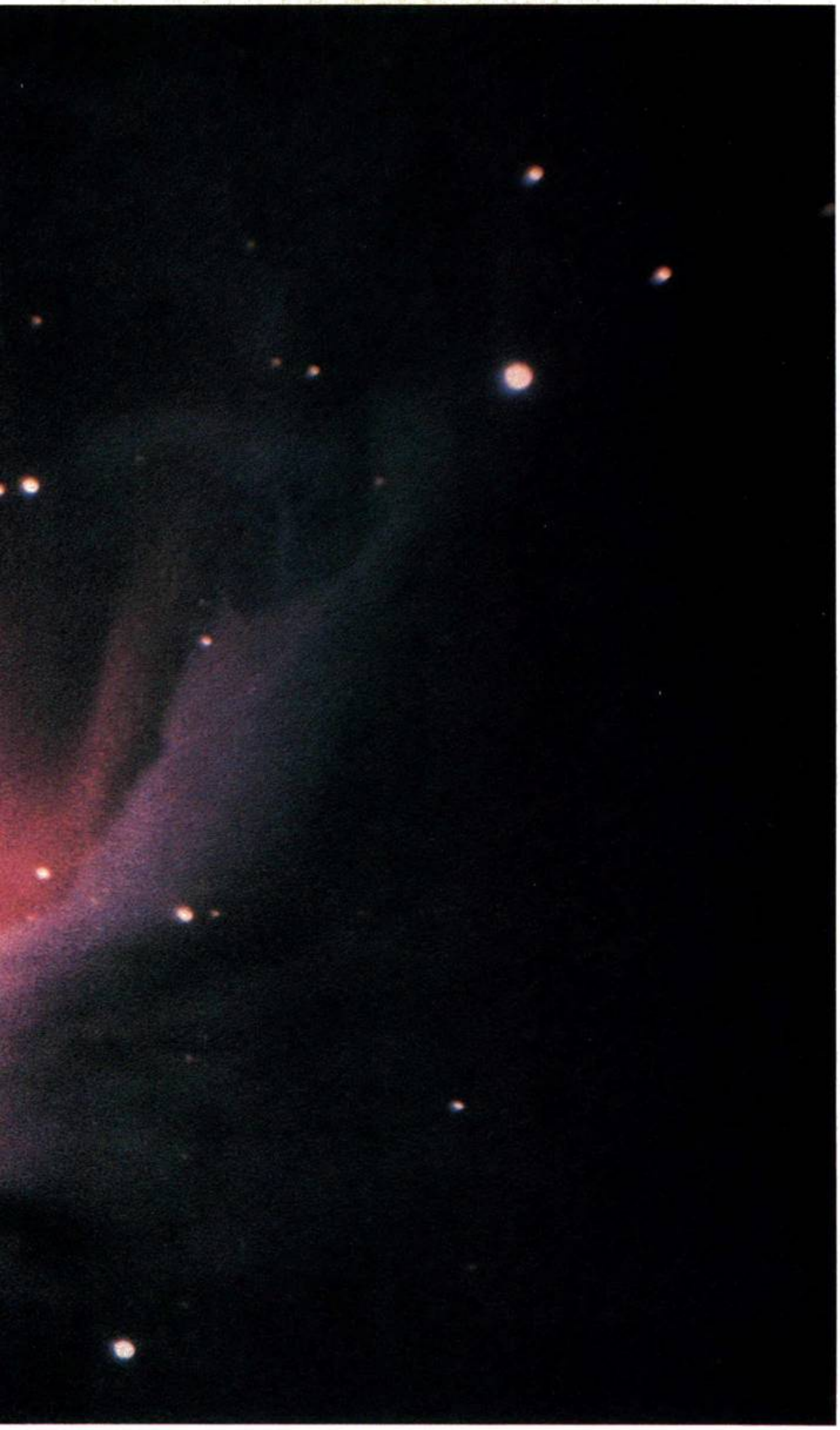


with a fast Newtonian can use a light-pollution filter and super-speed film, long focal lengths and slow f/ratios together confer two distinct advantages. First, a long focal length translates into a larger image size. This means you don't have to enlarge the negative or slide as much and therefore grain (inherent in all super-fast films) becomes less noticeable. Second, a slow f/ratio sharply reduces the sky fog, thereby yielding a darker background and better image contrast.

With some objects and under certain sky conditions, I've found I don't even need a light-pollution filter. If you have a long focal-length telescope system and you get one of those marvelously transparent nights, choose one or two of the brighter deep-sky objects (M42 or the Rosette Nebula) and try a couple of backyard shots *without* a filter.

Wait until the object is on the meridian — or away from the worst of your city's sky glow. The photos of the Orion Nebula above and the Dumbbell Nebula on page 95 show this isn't impossible — both were taken unfiltered from a suburban location. But remember that the key is to wait for only the clearest nights, use a slow f/ratio, and catch the object when it's highest.

Ordinarily you would expect the slow focal ratios and heavy filtration to impose punishingly long exposures. But these new films are so fast you can capture the brighter Messier



LONG F/RATIOS produce dark skies even without a filter: the Orion Nebula, taken with 3M 1000 film, a 10-inch SCT, and a 26-minute exposure at f/13.5.

objects in about 30 minutes.

I regularly use 10-inch and 14-inch Schmidt-Cassegrains at prime focus (f/11 to f/13.5) or at f/7 or f/8 with a telecompressor. I use an off-axis guider with a 12mm illuminated reticle eyepiece and a 2x Barlow lens. On my camera I use a clear or matte-type interchangeable focusing screen with cross hairs and a right-angle magnifying focuser. (I strongly recommend a magnifier for focusing any SLR, even if the viewing screen is fixed.)

When I want to capture a wider field of view than an SCT provides, I use a 200mm f/4 lens or a 3-inch f/6.3 apochromat (500mm focal length) mounted piggyback on the telescope. Most modern medium and long focal-length telephoto lenses are quite acceptable for this type of photography. Try to avoid zooms, however. Even the best designs tend to suffer from more internal reflections and often give less-than-pinpoint star images when compared to nonzoom lenses.

Out with the Bad Light . . .

I use Lumicon's Deep Sky (DSF) and Ultra-High Contrast (UHC) filters. These enhance contrast — particularly the UHC with hydrogen emission nebulae — and eliminate background light pollution almost totally. They lengthen the exposures considerably (an acceptable tradeoff because the results are great) and can sharply alter the color characteristics of some films (ditto, because, as you'll see, they're usually correctable). In my experience the DSF works very well with 3M 1000, both Konica 1600 and 3200 films, and Kodak's black-and-white Technical Pan. But it is less satisfying with Ektachrome because images appear excessively red.

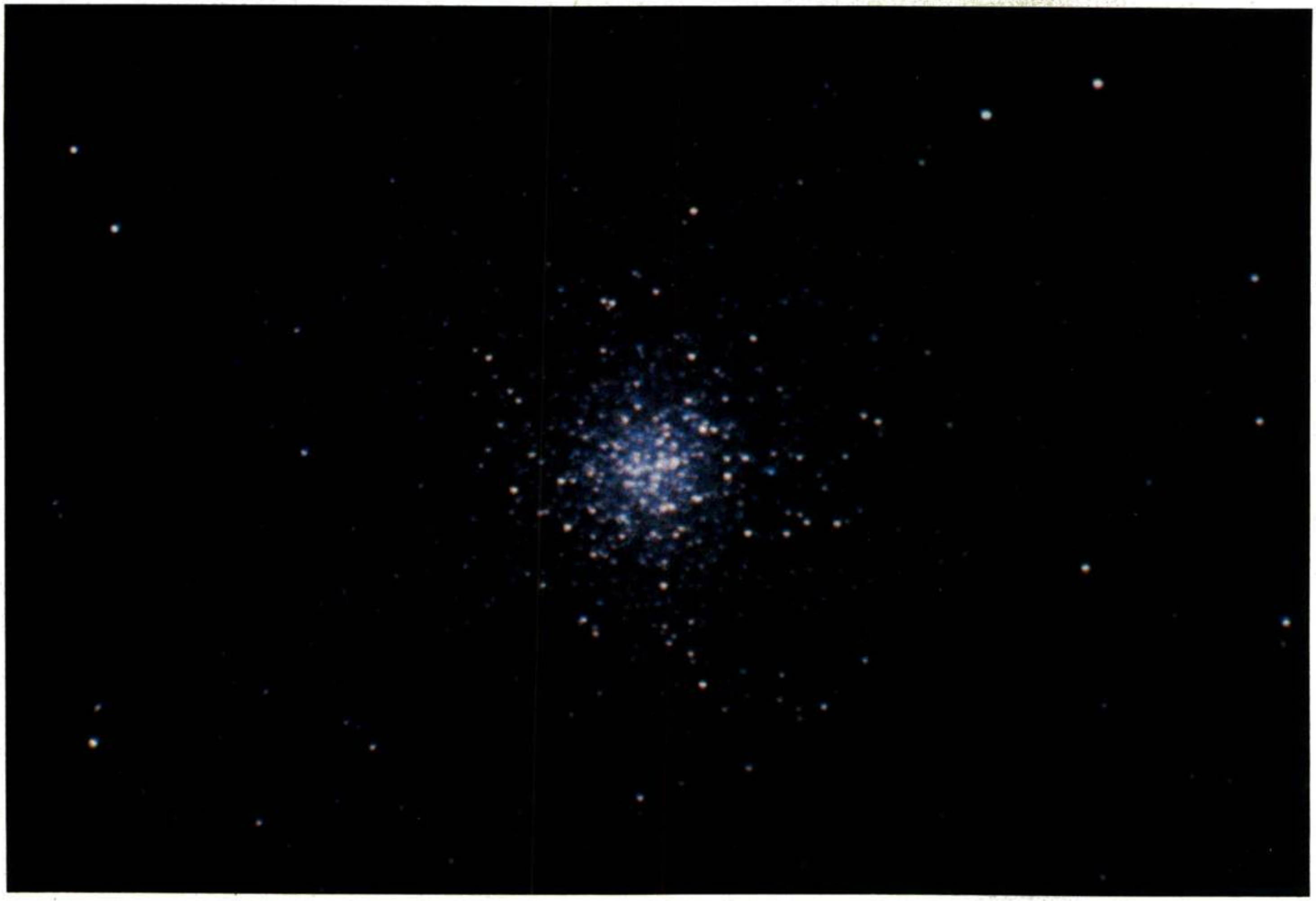
In the most common size, these filters have a diameter of 48 millimeters. (You can also get a 72mm Deep Sky filter for a lot more money.) If the filter size doesn't match your camera lens' filter threads, get a step-up (or step-down) adaptor from a photo store.

Except for one comparison image of M8 (page 94) taken at the 1986 Texas Star Party, all photographs shown here were taken from suburban backyard sites. These include Kingston, Ontario, (a community of about 100,000) and Tulsa, Oklahoma, with a metropolitan population of more than 500,000. Sky conditions at both locations are probably typical of many small- to medium-size cities in North America: moderate to heavy light pollution, with the worst effects in the sector of sky toward the city center. On exceptional nights you might see a hint of Milky Way, but these are increasingly rare.

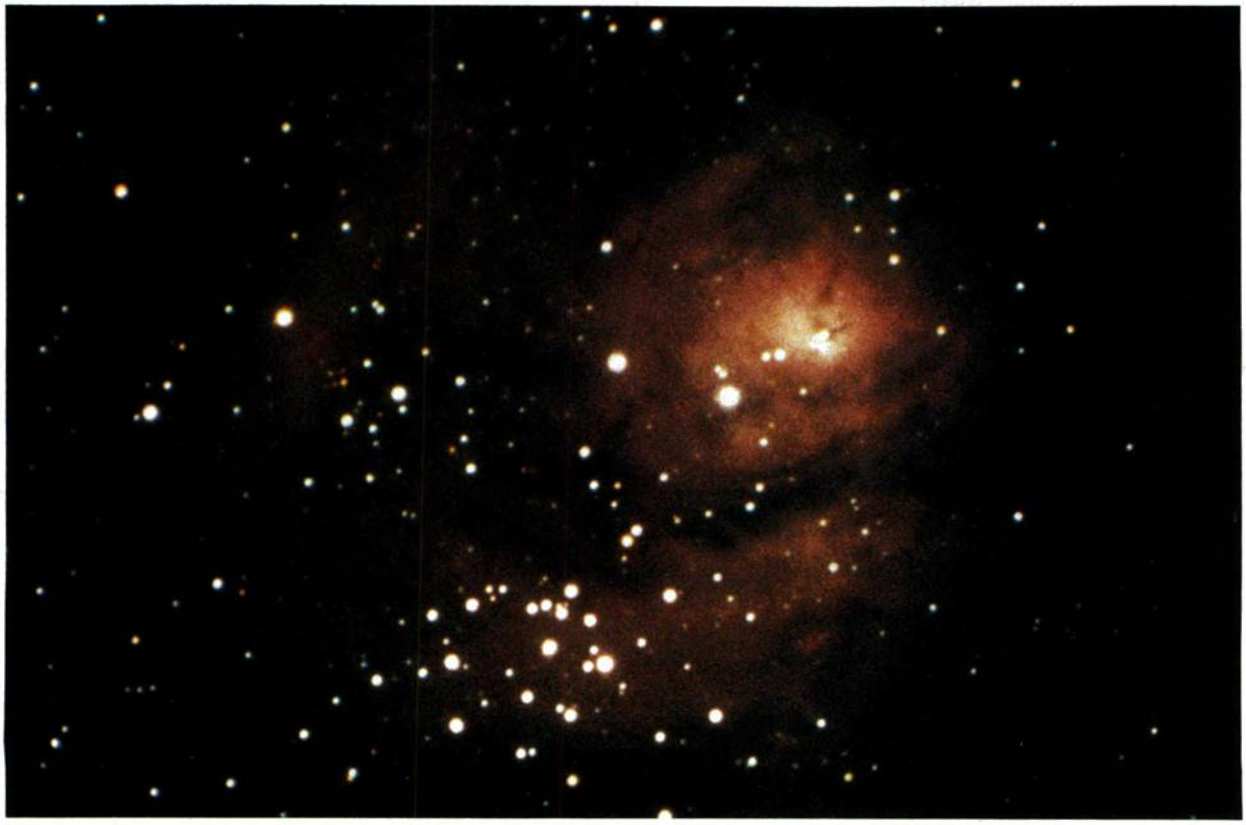
Astrophoto Films in Parade

Konica 3200 and hypered Konica 1600 are clearly the films of choice for prints. Although you can mail order it hypered, the 3200 film is already super fast and loses little speed (or color balance) during a long exposure. Both films are tops for speed, have remarkably fine grain, and are highly responsive at all f/ratios.

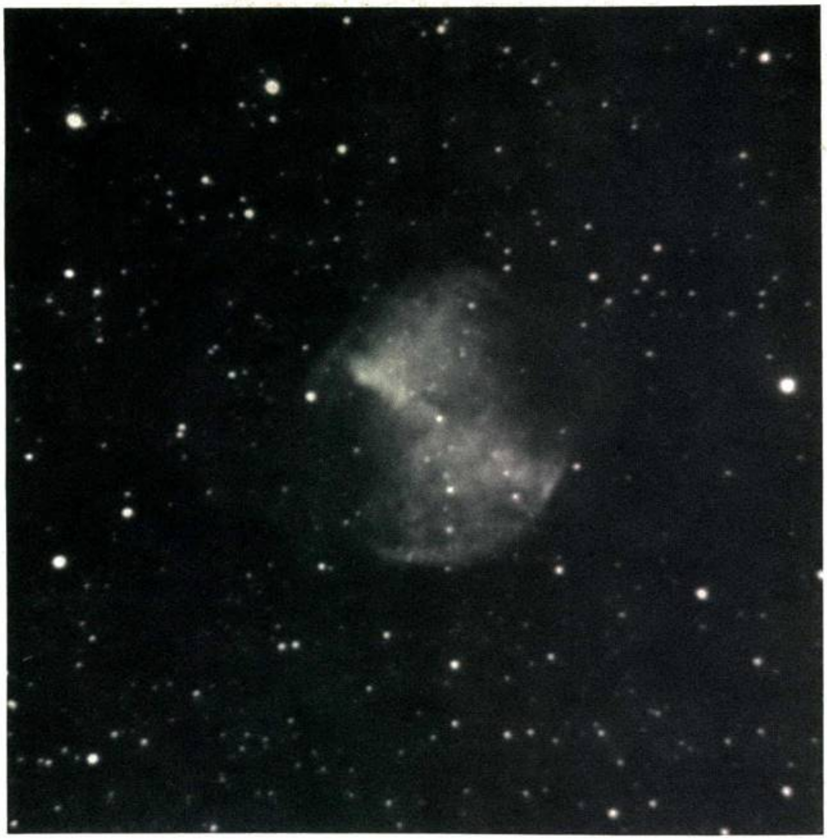
In slide films, all the Ektachrome emulsions are quite satisfactory in terms of resolution and image contrast. A marginal increase in graininess is evident with the 800/1600-speed film (compared to the old 400-speed film), but the faster film exhibits better color balance, especially with emission nebulae. (Moreover, it can be



COPYING M13 (18 minutes on Konica 3200 with a 14-inch SCT at f/11) onto Vericolor turned a negative image into a pleasing positive.



DUPING WITH A 30C FILTER corrected the color in M8 (10-inch SCT at f/8 on 3M 1000 film with a 23-minute exposure).



RELATIVELY BRIGHT, the Dumbbell Nebula (M27) photographs well at long f/ratios; 45 minutes on hypered Tech Pan with a 10-inch SCT at f/8 caught it neatly.

Six Handy Tips

1. Take advantage of dry, moonless nights — after a cold front passes, for example. Also photograph later at night: sky glow starts to diminish around 11 p.m.

2. Whenever possible, **aim away from the center of the city** and try to catch your targets near the meridian rather than the horizon.

3. Always use a dew cap with a Schmidt-Cassegrain, both to prevent condensation on the corrector lens and to shield the lens from stray light. (A simple tube of stiff, flat-black paper board is perfect.) Also shield telephoto lenses.

4. Refocus carefully between exposures with the filter in place. For the sharpest images use a matte or clear focusing screen with cross hairs and a magnifying focuser. (Magnifying focusers are available for most SLR cameras, even those with noninterchangeable screens.) If you can't focus on a nebula directly, use a nearby star.

5. Keep a careful log of each photo you shoot. Note object, date and time, sky conditions, film (and processing), f/ratio, and exposure.

6. Start simple: **Begin with 5- to 10-minute exposures** with the camera mounted piggyback.

pushed to ISO 3200 and 6400, though grain really begins to become noticeable.) I find that Ektachrome 800/1600 has stronger blues than the 400-speed Ektachrome, in which reddish pinks predominate.

The 3M 1000 slide film is fast even when unhypered. Unfortunately it is also quite grainy. And though the slight greenish cast characteristic of this film is minimal in photos taken at f/13.5, it becomes annoying at f/8. The film works well however on bright emission nebulae, with and without a DSF filter and/or enhancement through duplication.

Love black and white? There's one outstanding fine-grain film for deep-sky astrophotography, Kodak's Technical Pan, type 2415. (Although coarser in grain, the new T-Max 400 is pretty good too.) When hypered, Tech Pan has no equal for deep-sky objects and unhypered it's excellent for lunar and planetary subjects. It is unrivaled for high resolution and contrast at both fast and slow f/ratios. Its good red sensitivity is also a plus when used with a filter, particularly a DSF. Now, if only we had a *color* film with these characteristics!

Duping for Quality

Any astrophotographer, urban or otherwise, should get a slide duplicator. This lets you make slides out of negatives and negatives out of slides and lets you correct color imbalances as you go. A simple zoom-type duper like the one Spiratone sells (see the company's ads in *Modern* or *Popular Photography*) works fine. A set of gelatin filters such as those used in color printmaking completes the outfit.

For duplicating slides, pick a fine-grain film. Kodachrome 25, Ektachrome 100, and Ektachrome Slide Duplicating Film (type 5071) are all suitable. To make slides from color negative film, use Kodak's type 5072 (SO-279), and for black-and-white slides, use Technical Pan right out of the box.

As a light source I prefer a regular 250-watt tungsten light bulb, but almost any light source will do as long as it isn't too strongly colored. I always assume I will be shifting the color balance in duping and the mismatch between the tungsten source and the daylight duping film has never been a problem. In any case, the Spiratone duper can be bought with a flash unit as the source, and the whole outfit is highly convenient.

As you experiment with various films, filters, and exposure combinations, you'll discover how far you can go to retrieve photos that initially look too strange in color. Very often a slide will show adequate detail but is simply too dark. A duper lets you rectify the undertimed exposure by overexposing when you copy the original. (The same holds true if you copy an overexposed negative.) A duper also lets you substantially improve even a very good original just by enlarging it and centering it in the frame.

I hope this article and photos will encourage others who live in cities to try their hand at deep-sky astrophotography. This stuff *works*. And while the technique can't totally replace a dark, un-light-polluted sky, it can certainly bolster the morale of any city-bound astrophotographer.

Klaus Brasch is a biology professor at the University of Tulsa. His academic and research interests include genetics, cell and molecular biology, and questions relating to the origin of life. Although a long-time amateur astronomer, he began serious astrophotography only a few years ago.

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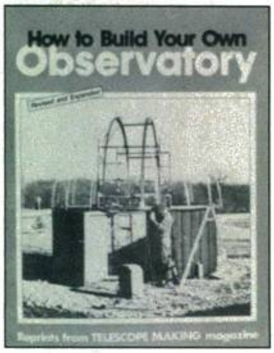

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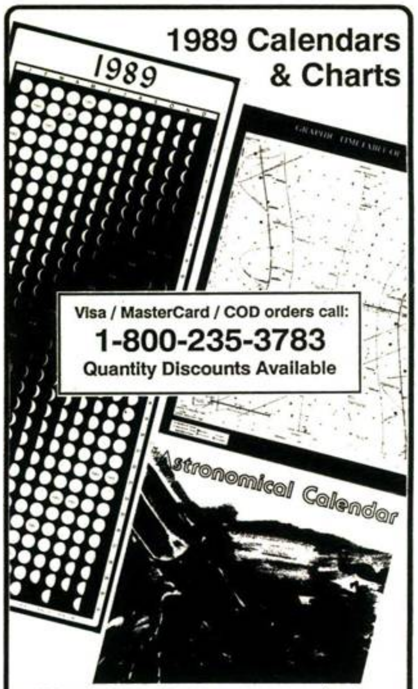

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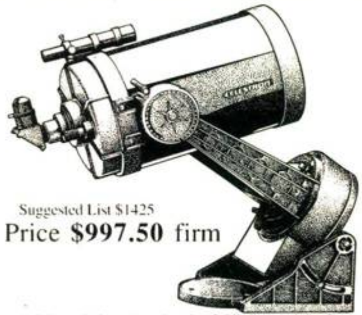

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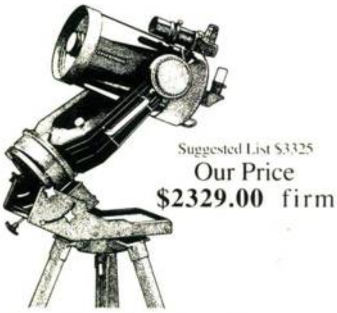

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Standout Winter Star Clusters

With a small scope you can discover a variety of star clusters that lie in the winter Milky Way.

by Alister Ling

The attraction of star clusters is simple. Star clusters are deep-sky objects every amateur astronomer or novice can enjoy. Unlike galaxies, bright star clusters pierce the cloak of light pollution in suburban skies, and because of this, star clusters are easy to observe with small telescopes even if the sky overhead is slightly hazy or somewhat bright.

Open star clusters are small groups of a few dozen to a few hundred stars that form from clouds of gas in the Milky Way's disk. Star clusters are fun to look at because no two are alike. Clumps, knots, and strings of material coalescing into stars create clusters with round or oblong shapes, irregular distributions of stars, and prominent chains or loops of stars stretching all the way across your telescope's field of view — distances that correspond to trillions of miles in space. Colors also play prominently: even with a telescope as small as 2 inches in aperture you will see stars of different colors in the brightest winter clusters.

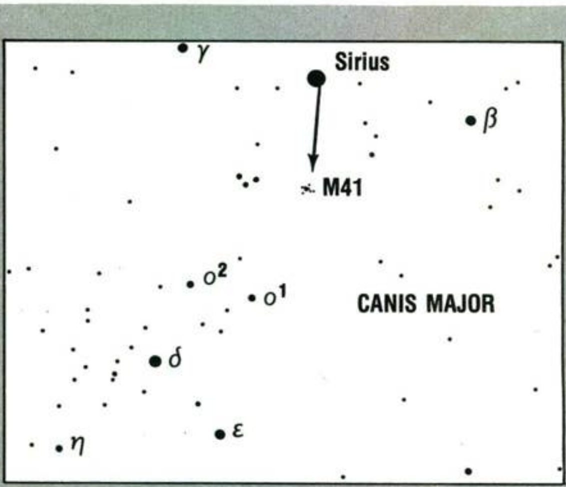
M41 (NGC 2287) is the best open cluster in the winter sky. From a dark site, this magnitude 4.5 cluster is easily visible to the naked eye. The cluster's position just 4° south of Sirius — the brightest star in the sky — makes finding it a snap. Simply aim your finder scope at Sirius, then slowly sweep south, and you'll come upon a tightly packed group of bright stars.

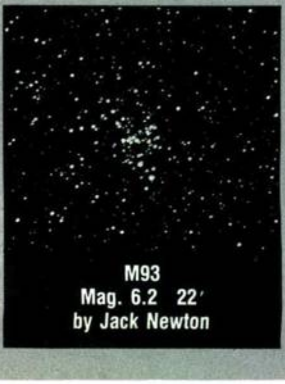
M41 measures over 40′ across — it's larger than the Full Moon! — so try observing it with a low-power eyepiece first. Relax and take a long, close look. Move your eye slowly around the field, carefully examining each little subgroup of stars that together forms the cluster. With such a wide field of view you can scan the entire cluster and the surrounding area all at once. Notice that even in a low-power eyepiece M41 appears large and round and holds several dozen bright stars.

If you're observing with a 4-inch or larger telescope, you'll see a scattered group of three dozen stars set against a blue-black backdrop. Although the cluster is generally circular, individual stars group into threes and fours within the cluster. A glance at the brightest star in M41, a 7th-magnitude gem located in the cluster's center, shows it is noticeably orange. Of the remaining dozen brightest stars, four others are orange and the others intensely blue-white. Do they all look white to you? Try putting the stars ever-so-slightly out of focus. This will help you see the colors more easily; they'll appear as colored fringes around the bright central star.

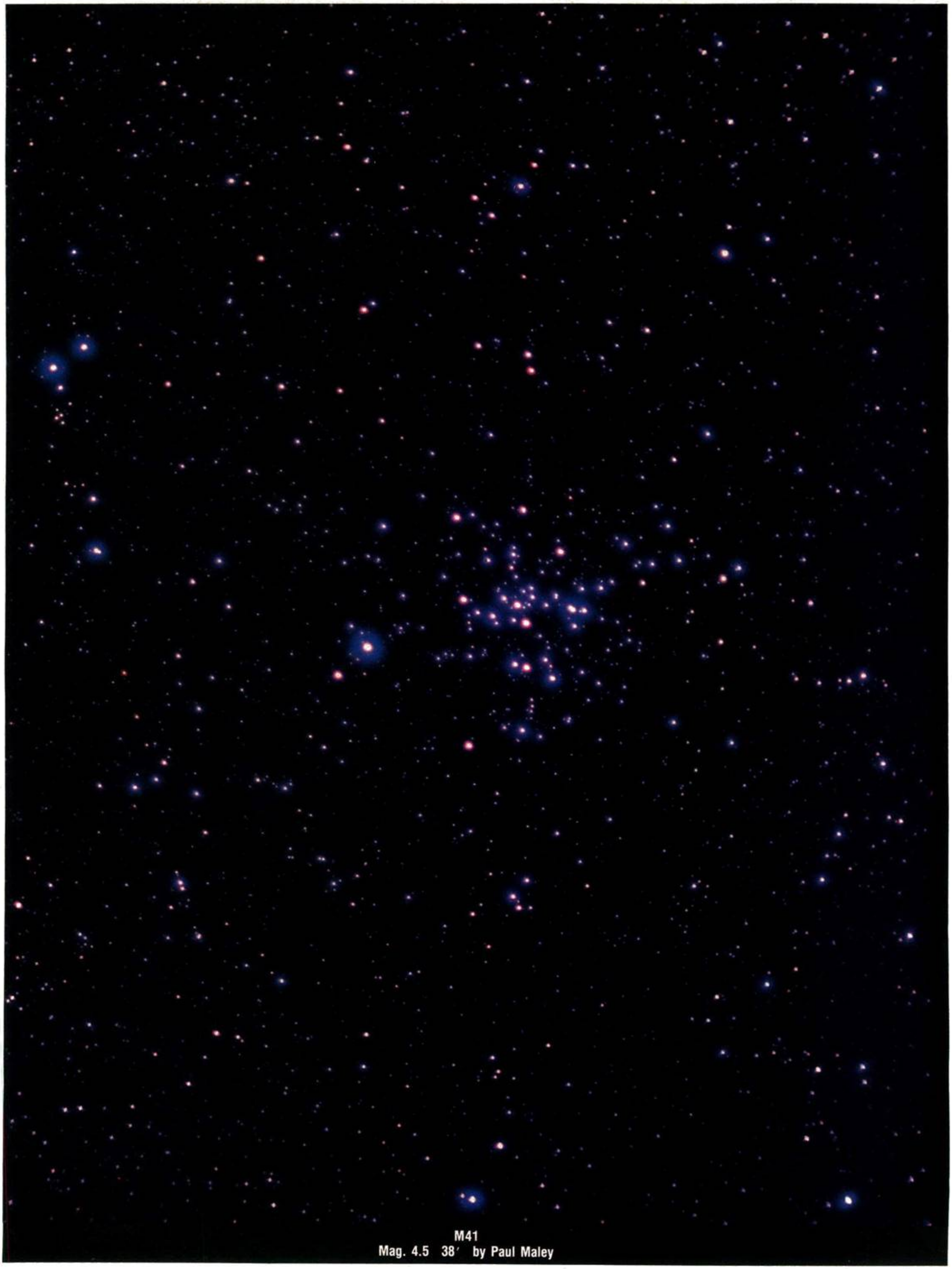
Unusual patterns of stars surround M41's central star. Shift your gaze east of the cluster's center and you'll see a concentration of bright blue, white, and orange stars. Just a few arcminutes northeast of the central star, two orange stars glowing at 8th and 9th magnitudes form the center of a C-shaped ring of six stars with its open end oriented northeast. Eight-inch or larger scopes show eight fainter stars in this figure, including a faint double comprised of twin white stars. Twenty arcminutes southeast of M41's center lies a 6th-magnitude blue star that is not a member of the cluster but simply a foreground object.

Several arcminutes southwest of the cluster's center lies a pair of 8th- and 9th-magnitude stars. The brighter

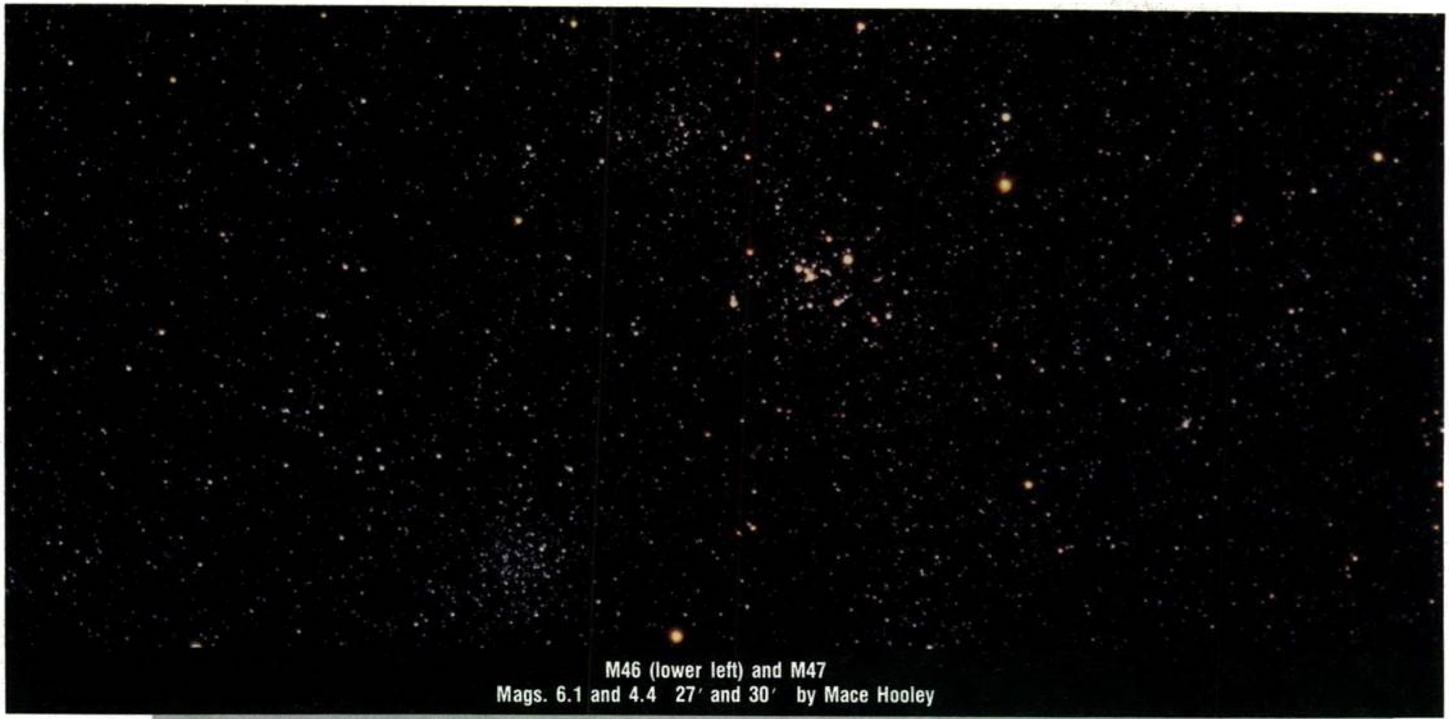



M93
Mag. 6.2 22′
by Jack Newton

SPARKLING M41 is located 4° south of Sirius, the sky's brightest star. A long-exposure photo (opposite page) shows the cluster's several dozen members. M93 in Puppis contains as many stars as M41 but is more condensed.



M41
Mag. 4.5 38′ by Paul Maley

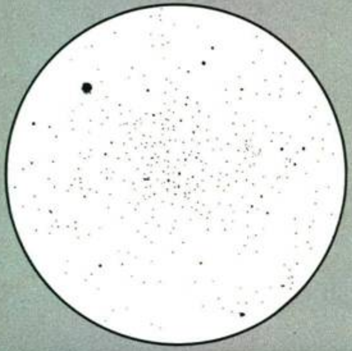


M46 (lower left) and M47
Mags. 6.1 and 4.4 27′ and 30′ by Mace Hooley

ONE HUNDRED FAINT STARS comprise the cluster M46 in Puppis. The planetary nebula NGC 2438 is a foreground object that appears to lie inside M46. Slightly over 1.5° west of M46 lies M47, a much brighter cluster.

M47
Mag. 4.4 30′ by Jack Newton

NGC 2438
Mag. 10.1 66″ by Jack Marling



M46
8-inch f/10 SCT 50x by David J. Eicher

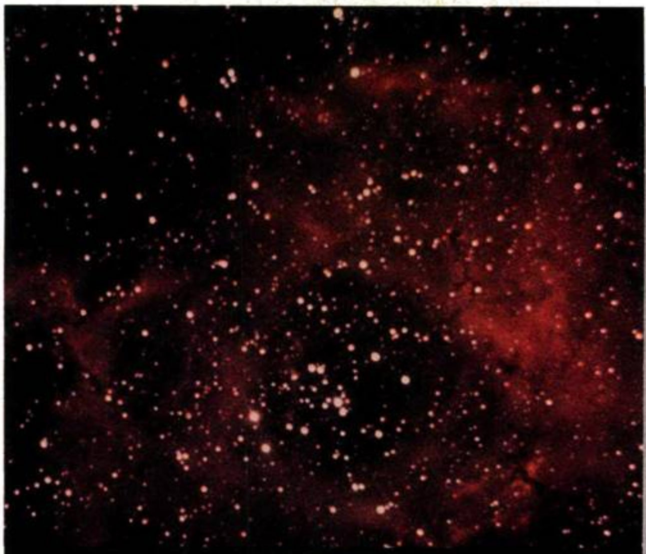
star has an orange tint and its companion is pale blue. This pair lies opposite the C-shaped ring relative to the central star. Slightly farther to the southwest a little row of four 11th-magnitude stars marks one of the easiest features to identify in M41. North of the double star you'll see a squashed triangle of stars readily visible in 4-inch instruments. North of the cluster's center lies a large clump of bright, blue-white stars — this area contributes significantly to the cluster's overall magnitude.

Scouting around the edges of the cluster, you'll notice how quickly the bright stars thin out in number. Now center the group and look about halfway out to the edge of the field of view, paying attention to the central area. This technique, called averted vision, is one of the most valuable tools in visual astronomy. Looking off to one side exposes the most light-sensitive part of your eye to the center of the cluster. Try it a few times — many "extra" stars will become visible and fill the cluster with faint stardust.

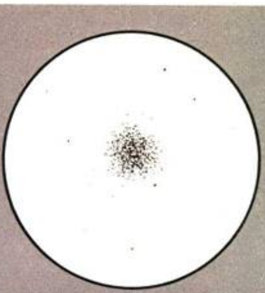
If you observe M41 on a number of nights, you'll notice it is satisfying even when the Moon is up or the night offers less-than-perfect seeing or transparency. This is the case with other clusters as well. Of course these objects look best when the atmosphere is steady and the Moon is out of the sky, but star clusters are observable just about anytime.

Unlike many small deep-sky objects, large open clusters like M41 are best seen in small or medium telescopes with fields of view large enough to include the entire cluster and some surrounding sky. Very large telescopes with their relatively small fields of view let you see only pieces of large clusters at a time.

One cluster compact enough to view with large scopes is **M93** (NGC 2447) in Puppis. To find M93, aim your finder scope at the bright double star Xi (ξ) Puppis and then move the telescope 2° northwest. You'll see a cluster much smaller than M41 but very bright — this object really stands out. Changing to a medium-power eyepiece will help to reveal M93's individual stars and will provide a slightly darker background sky to see stars against. (This is a useful technique for looking at small- and medium-size clusters.) Use a magnification that shows M93 about as spread out as your low-power view of M41.

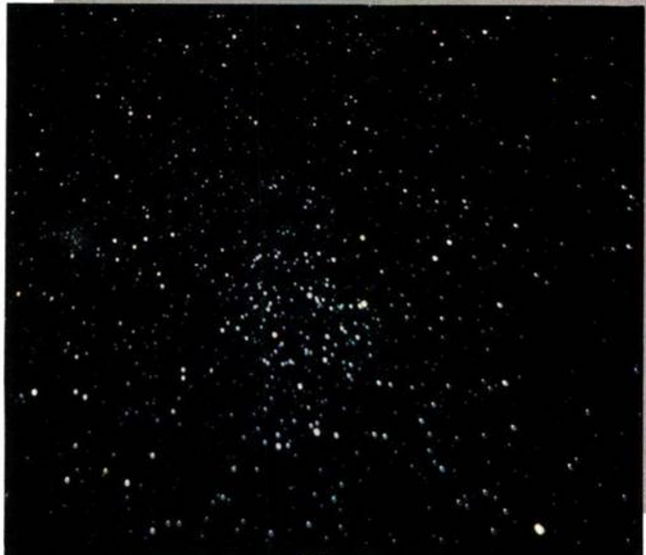


NGC 2244
Mag. 4.8 24′ by Chris Floyd

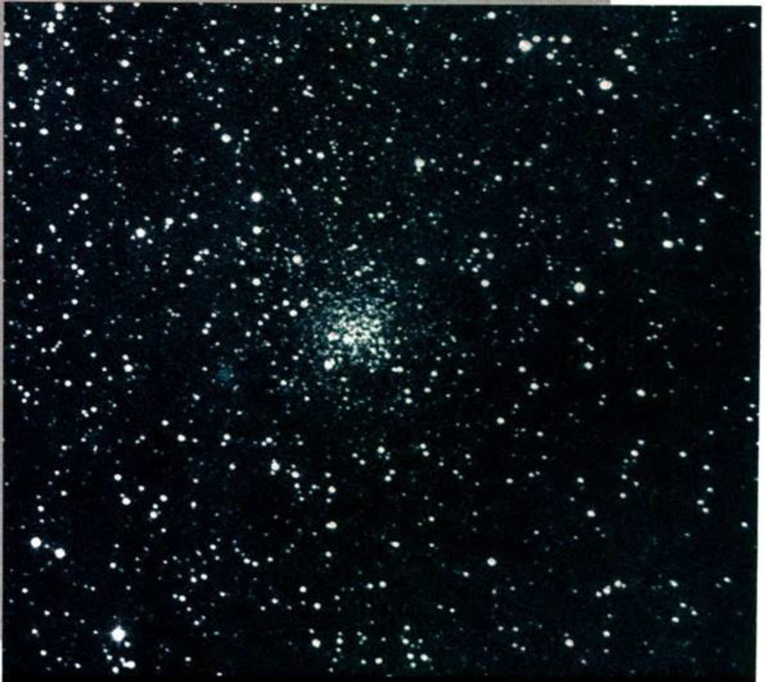


NGC 2158
17.5-inch f/4.5 Reflector 142x
by David J. Eicher

AS LARGE AS THE MOON, Gemini's M35 is visible to the naked eye on dark nights. M35's companion cluster is NGC 2158, a small collection of faint stars 30′ southwest of M35's center. Twenty degrees southeast of M35 in Monoceros lies NGC 2244, a bright cluster encircled by the Rosette Nebula.



M35
Mag. 5.1 28′ by Mace Hooley



NGC 2158
Mag. 8.6 5′ by Lee C. Coombs

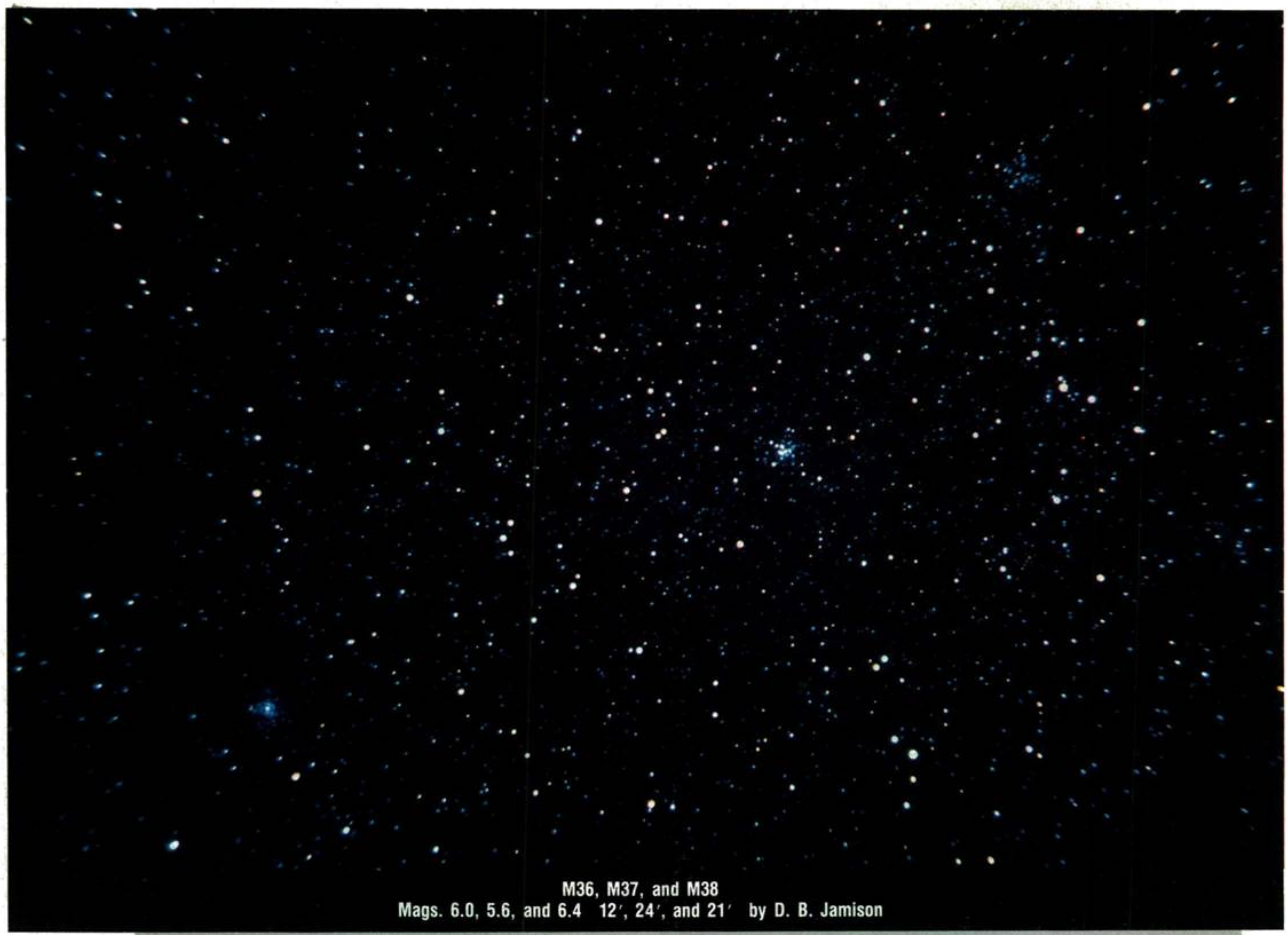
M93's stars are slightly fainter than those in M41, and the dimmest members sometimes appear to get lost in the rich Milky Way starfield that surrounds M93. Unlike the stars of M41, M93's members more or less clump together in a band aligned east-west, with a wedge-shaped appendage extending to the north. This object strikingly resembles an arrowhead, something you'll notice right away with a 6-inch or larger scope.

Some 8° north of M93 lies a delightful tangle of 5th- and 6th-magnitude stars known as **M47** (NGC 2422). This cluster is dramatically different than M41. M47 shows a vast range in brightness between its most and least luminous stars — the bright blue stars shine nearly ten magnitudes brighter than the faintest, which are invisible in small scopes. The bright blue stars in M47 are scattered randomly across an even, circular background of dim stars. Because it contains many faint stars, M47 benefits greatly from viewing under a dark, country sky. Under these conditions the lower the power you use, the better M47 looks.

Moving east from M47, you'll encounter **M46** (NGC 2437) some 90′ away. This cluster is almost the same size as M41, but its stars are much fainter. If you're using a small telescope in a light-polluted area, you may have trouble spotting M46, but a 6-inch scope from a dark-sky site shows it well. You'll see that nearly all of M46's stars glow at about the same magnitude. Low powers are required to see all of this group's large, circular outline.

But before you pass on to another cluster, switch to moderate or high powers, which will reveal a curious ring-shaped nebula on the cluster's northern edge. This is NGC 2438, a slightly fainter version of Lyra's famous Ring Nebula. NGC 2438 is a planetary nebula — the gaseous remains of a dead star — merely masquerading as a member of M46. NGC 2438 is actually a foreground object. On nights when the seeing is good, try to spot two stars *inside* NGC 2438. These stars are not associated with the nebula, they only appear to be.

Our next object lies northeast of Orion's bright star Betelgeuse and is buried in the middle of the winter Milky Way. **NGC 2244** is a sparkling cluster that energizes a large, glowing wreath of light called the Rosette Nebula. NGC 2244 is quite similar to M41 in that many of its stars are bright, blue-white beacons that can be seen on prac-



AURIGA'S TRIO OF BRIGHT CLUSTERS consists of M36 (center), M37 (lower left), and M38 (upper right). M36 and M38 are large star groups visible in finder scopes; M37 is similar to Scutum's rich Wild Duck Cluster.

tically any clear night. They display a wide range of brightnesses, some glowing as dimly as 14th or 15th magnitude. In this respect it is also similar to M41. However, NGC 2244's brightest stars form a box shape rather than a clumpy distribution, and here the similarity ends.

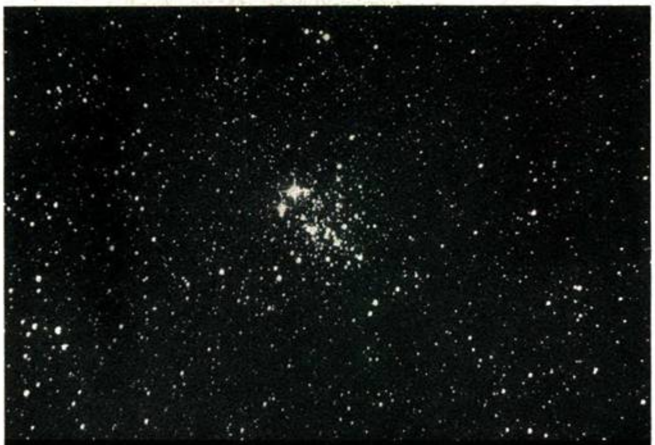
The stars of NGC 2244 are visible in a 3-inch telescope even when the atmosphere is not perfectly steady. A large field of view is required to see the entire cluster because it spans over 1°. At a dark sky site a 6-inch or larger scope reveals the faint glow of the Rosette Nebula encircling NGC 2244.

North of the Rosette Nebula lies Gemini, home of one of the finest clusters in the sky. **M35** (NGC 2168) is an enormous (over 1°-diameter) cluster visible to the naked eye in moderately dark skies. The stars in M35 scatter so widely that your lowest-power eyepiece will provide the best views. The wide range of brightnesses of stars in M35 — from 5th magnitude to beyond visibility — and easy geometric patterns of stars mean this cluster is a good place to start sketching. You can begin with the bright stars and fill in progressively fainter ones. You can even continue your sketch a few nights after you begin. The prominent patterns in M35 — triangles, squares, and arcs — make sketching the stars easy and fun.

If you observe M35 with an 6-inch or larger telescope, you may see a small, concentrated patch of fuzzy light about one Moon-diameter southwest of M35. This is **NGC 2158**, an open cluster similar to M35 but six times more distant. Because of this, its faint stars and arrowhead shape require high power to see clearly.

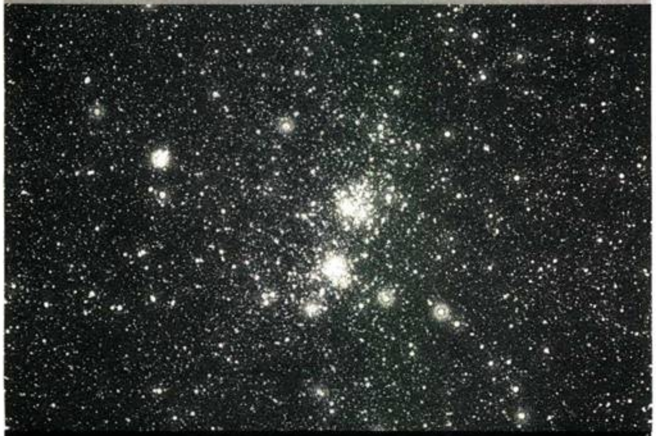
Auriga's trio of Messier clusters — M36, M37, and M38 — differ from one another and from M41 in substantial ways. **M38** (NGC 1912) is similar to M35 in Gemini because of its great, scattered collection of stars and geometric star patterns. It also has a small companion cluster, NGC 1907, that is visible in large scopes much as NGC 2158 is. M38 contains a wide range of bright and faint stars, in contrast with **M36** (NGC 1960), which leaps out of the background with a dozen bright stars. One of the southernmost stars is a bright pair. While there are bright stars near the center of M36, there is no great central concentration like the one in M41. This is a nice feature of open cluster observing: each cluster has its own individual characteristics.

M37 (NGC 2099) is the "Grand Cluster of Auriga," a wintertime version of the rich and beautiful Wild Duck Cluster in Scutum. The lone bright star in M37, a 9th-magnitude orange star, is the cluster's most distinctive member. M37 is a breathtaking object under a dark sky, when its triangular mass of faint stars includes dozens that spill outside of a low-power field, which leaves dark



NGC 457
Mag. 6.4 13′ by Lee C. Coombs

NORTHERN MILKY WAY CLUSTERS NGC 457 in Cassiopeia and the Double Cluster in Perseus are bright enough to observe with any telescope.



NGC 869 (bottom) and NGC 884
Mags. 4.3 and 4.4 30′ and 30′ by Jean Dragesco

Winter's Best Star Clusters

Object	R.A. (2000.0)	Dec.	Magnitude	Size	*Tirion*	*Uranometria*
NGC 457	1h19.1m	+58°20′	6.4	13′	1	I: 36
NGC 869	2h19.4m	+57°09′	4.3	30′	1	I: 37
NGC 884	2h22.4m	+57°07′	4.4	30′	1	I: 37
NGC 1907	5h28.0m	+35°19′	8.2	7′	5	I: 97
M38 (NGC 1912)	5h28.7m	+35°50′	6.4	21′	5	I: 97
M36 (NGC 1960)	5h36.1m	+34°08′	6.0	12′	5	I: 97
M37 (NGC 2099)	5h52.4m	+32°33′	5.6	24′	5	I: 98
NGC 2158	6h07.5m	+24°06′	8.6	5′	5	I: 135, 136
M35 (NGC 2168)	6h08.9m	+24°20′	5.1	28′	5	I: 136, 136
NGC 2244	6h32.4m	+04°52′	4.8	24′	11	I: 227
M41 (NGC 2287)	6h47.0m	−20°44′	4.5	38′	19	—
M47 (NGC 2422)	7h36.6m	−14°30′	4.4	30′	12	—
M46 (NGC 2437)	7h41.8m	−14°49′	6.1	27′	12	—
NGC 2438	7h41.8m	−14°44′	10.1	66″	12	—
M93 (NGC 2447)	7h44.6m	−23°52′	6.2	22′	19	—

Object: Designation in Messier or NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Magnitude:** V magnitude of cluster. **Size:** Diameter in arcminutes or arcseconds. ***Tirion:*** Chart on which object appears in *Sky Atlas 2000.0* by Wil Tirion. ***Uranometria:*** Volume number and chart on which object appears in *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi.

lanes and star chains meandering through the eyepiece.

NGC 457 is the finest cluster in Cassiopeia. Large binoculars or small scopes show the two bright "eyes" in this star group nicknamed the Owl Cluster. The brightest of the eyes, orangy Phi (ϕ) Cassiopeiae, is one of the brightest stars known. The owl's body is composed of doublets and triplets of mainly yellow stars, and two thin wings stretch out from the body. The eastern wing contains an exceptionally red star about halfway along its length. High powers and averted vision reveal the glitter of background stardust, the light from dozens of faint, unresolved stars.

King of the northern sky's star clusters is the **Double Cluster** in Perseus, NGC 869 and NGC 884. Located just south of the bright "W" of Cassiopeia, the Double Cluster is easily visible to the naked eye as an oval glow even on nights of average transparency. The easternmost component, NGC 869, is the brighter of the two clusters. Use the lowest possible magnification to capture the two clusters in a single field of view. The central luminary in this group is located at what appears to be the neck of a humanlike stick figure of stars. To the south is a little circlet that forms the head, while to the north are two straight legs. High power reveals an extraordinary number of stars in this area, including some faint red stars.

NGC 884, the western half of the Double Cluster, is equal in size to its neighbor and only slightly fainter. Notice the variety of subtle star colors in NGC 884: blue, blue-white, white, yellow, orange, and even red stars are visible. Seldom does a group of stars allow you to see virtually every color of star in one small area.

While you warm up indoors after viewing the bright star clusters of winter, think about what you've seen.

Quite different from some of the summer clusters, the winter clusters are quite young. M41, a moderately young cluster, is approximately 190 million years old. Others range from the exceedingly young — like the Double Cluster's two members (3.2 million and 5.6 million years) and NGC 2244 (3 million years) — to the aged cluster NGC 2158 (3.2 billion years). Its great age reveals that NGC 2158 is not a part of the Orion arm — it is a distant background object lying 15,000 light-years away compared with M41's distance of 2,000 light-years. NGC 2158 is visible *through* the Orion arm of the Galaxy.

The winter clusters are typical in size, ranging from 12 light-years in diameter (M47) to 60 light-years across (each component of the Double Cluster). Most of the bright clusters, including M41, are 20 to 25 light-years in diameter. Starlight, traveling at 186,000 miles per second, takes twenty-five years to traverse the diameter of a cluster like M41. Standing under the crisp skies of winter, staring into a chilled eyepiece, you'll get the message that hits hardest — the universe is *big*.

Armed with a telescope and wrapped up to keep warm, you can witness a great deal of the Galaxy by observing bright winter clusters. On one level you can see the diversity that characterizes open star clusters — the bright central stars of M41 and M37, subtle star colors in the Double Cluster, and the fuzzy splash of light called NGC 2158. After observing these star groups, you'll see that each open cluster has qualities that separate it from the rest. On another level you can see that in the sky's great sea of black a few small clumps of stars mark an ancient, fundamental process in the Galaxy — the formation of new stars from old ones. □

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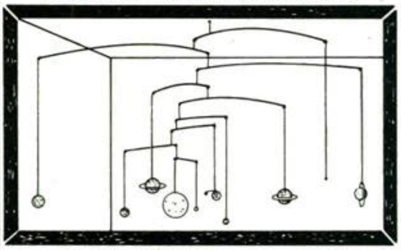

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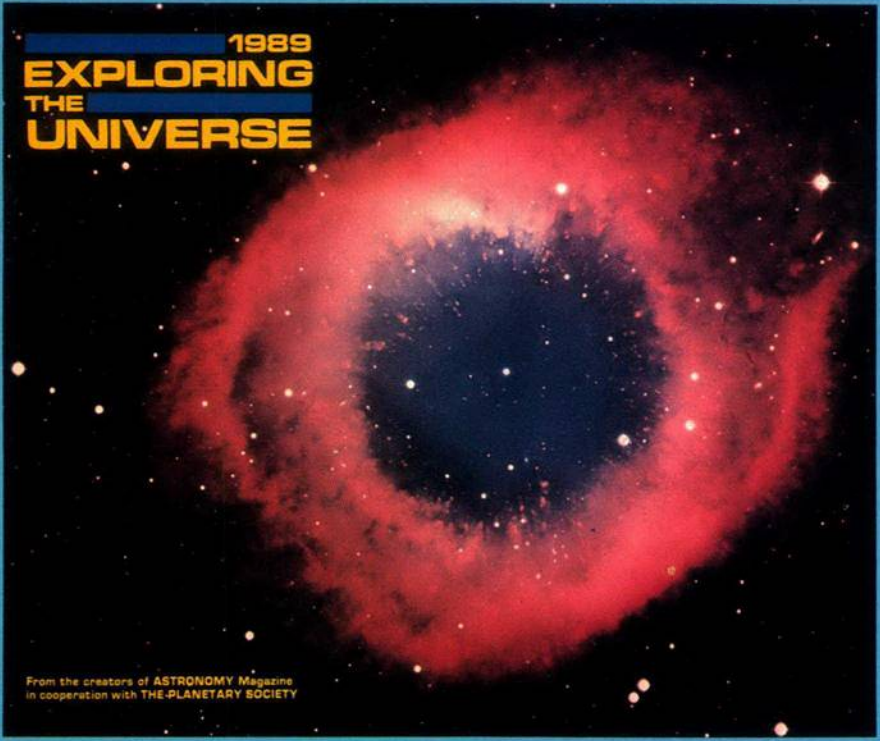
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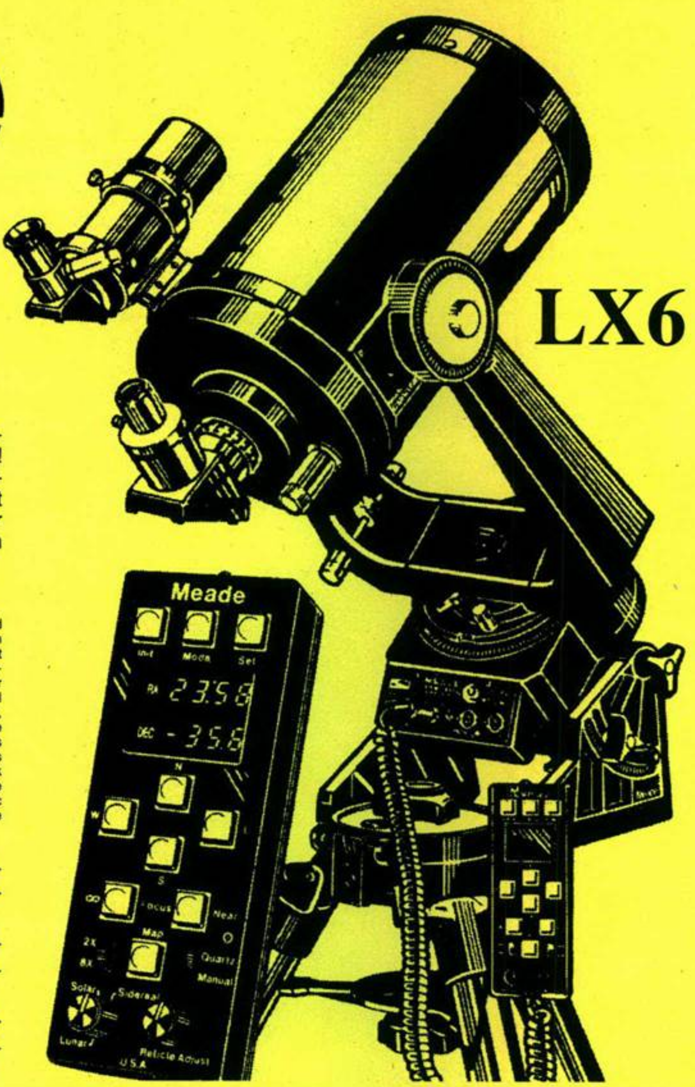

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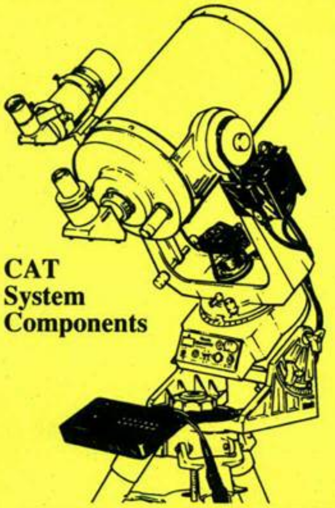

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For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kby diskette, with backup source-code listings in the instruction manual.

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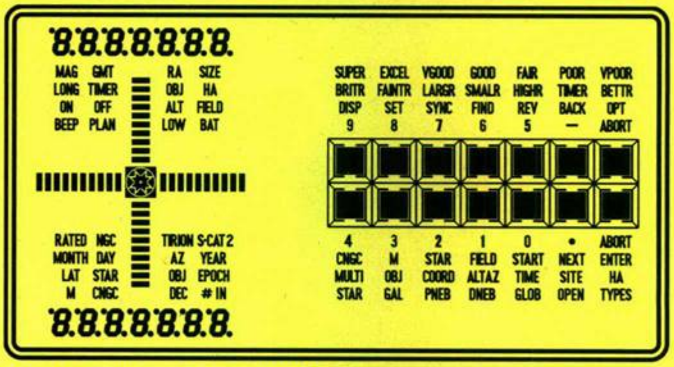

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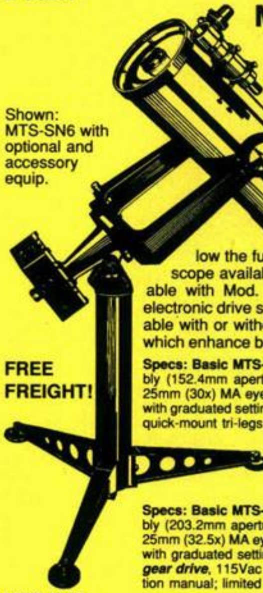
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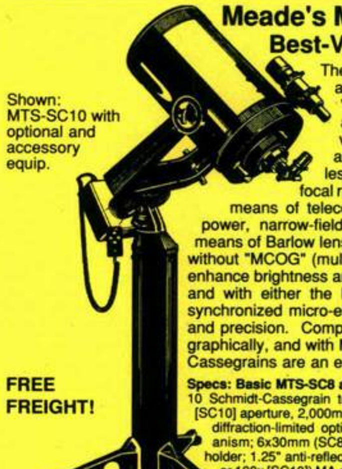
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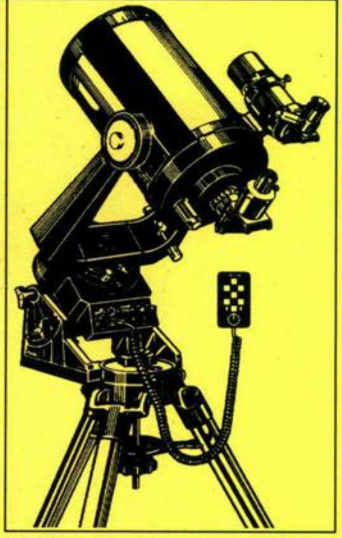

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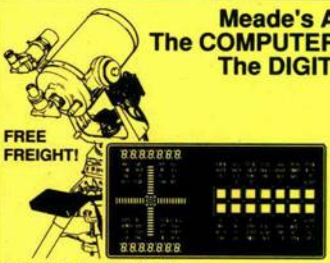
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CLEAR VIEW OF MARS DELIGHTS OBSERVERS

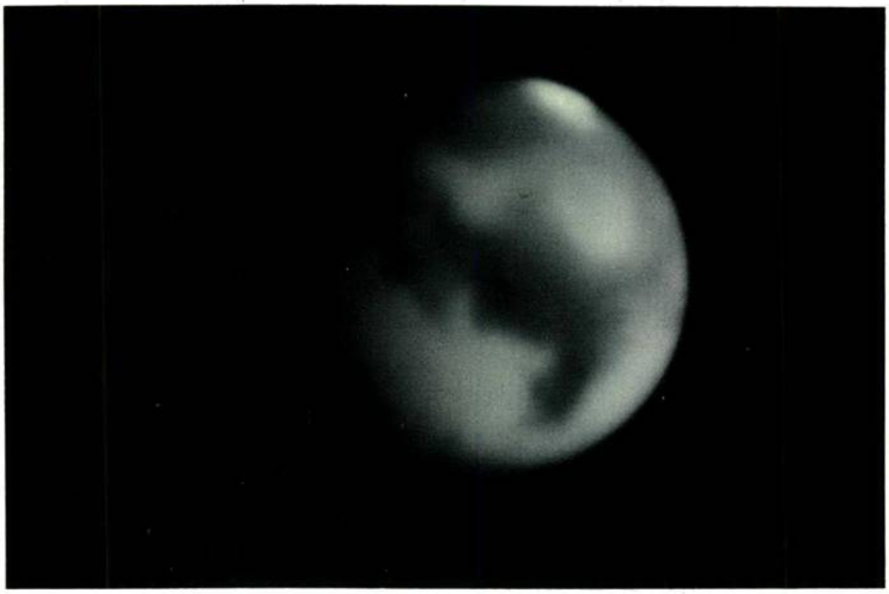
Mars loomed large and bright as it passed opposition last September 22. To everyone's delight the planet's atmosphere remained free of large-scale dust storms — something Mars experts feared might cloud the view of surface details — so Mars watchers with enough spunk to head outside witnessed the planet at its best since 1971.

Taking advantage of the planet's great size — 24″ at opposition — many astronomy clubs held public Mars watches. Three of the largest took place on September 21, 22, and 23, at the Orlando Science Center in Florida. To accommodate expected crowds, the Central Florida Astronomical Society provided two dozen telescopes including an 11-inch SCT that supplied video images to a viewing screen inside the science center. "The sizes of the crowds were astonishing," said Tim Printy, president of the Orlando group. Over six thousand people saw "live" images of Mars on television during the three-night period. Eager to learn about the Red Planet, newborn stargazers asked a barrage of questions: "How far away is Mars? What is the polar cap made of? What are the markings visible on the planet?"

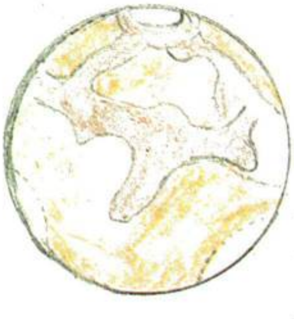
Jeff Adkins, a high school science teacher, held a Mars party on September 22 in Richmond, Kentucky. According to Adkins, "We sent a press release to approximately 120 schools in Fayette County, Kentucky, and to radio and television stations. Our local newspaper ran a front-page story, and WKYT, the local CBS affiliate, broadcast live as we set up telescopes. Several hundred people, predominantly students who had never seen Mars, showed up to get a look at Mars through 4-inch and 10-inch telescopes. To give our visitors background on what they were seeing, we put together displays describing the Red Planet."

Individual observers also took advantage of the prime Mars viewing. Steve Fetters of New River, Arizona, observed Mars with an array of colored filters on June 14. His notes describe the benefits of using filters for seeing various Martian features. "I set up my 6-inch f/8 reflector and used an eyepiece that yielded 96x," explained Fetters. "Mars was relatively close to the horizon, so I observed M30 and M72 for a while and turned the telescope back on Mars when the planet was higher in the sky. I found that 133x provided the most pleasing image of the planet — at this power its disk was huge!

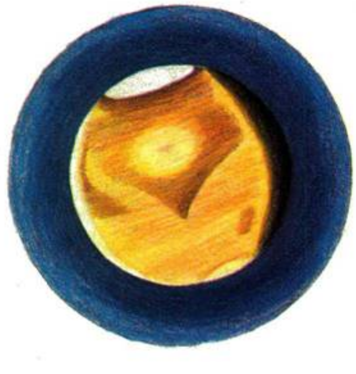
"The brightness of Mars made seeing



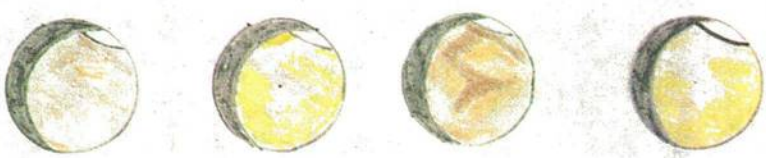
AT OPPOSITION the Red Planet grew to 24″ across, revealing fine details in small telescopes. Don Parker's photo made on August 25 shows Syrtis Major at right center; the Hellas basin is the light area above it. South is up in all images in this article.



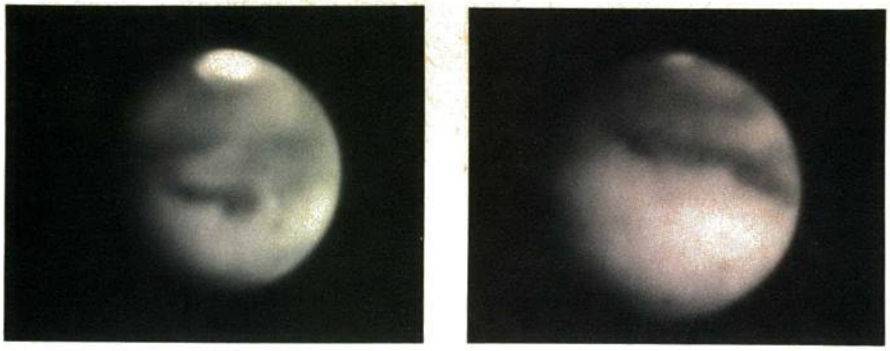
SKETCHING MARS caught on as observers familiarized themselves with the Martian surface. Steve Fetters' drawing shows Mars as it appeared on September 2 in a 6-inch f/8 telescope at 133x.



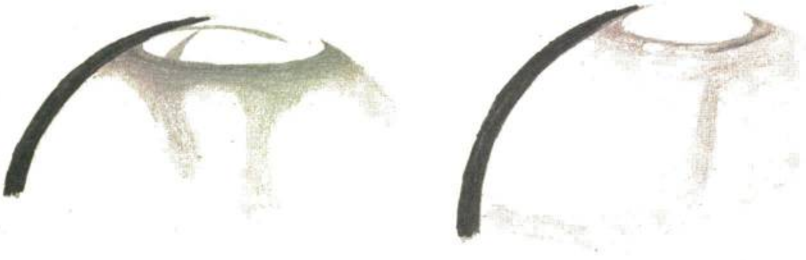
COLORED PENCIL renders subtle colors ranging from the stark white Southern Polar Cap to tawny brown maria. Light ocher Hellas dominates Clyde Kirkpatrick's sketch made with a 10-inch f/10 SCT at 202x on July 23.



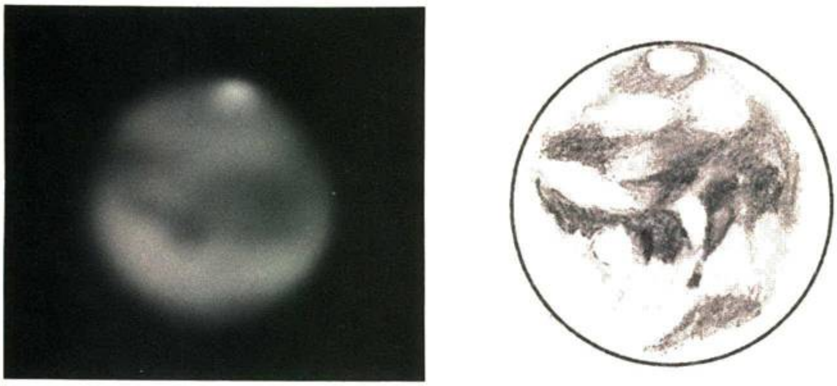
FILTERS REVEALED Martian features otherwise lost to view. A filterless view (left) hinted at surface features. Adding a Wrattan #8 yellow filter (second from left) helped, but markings were pale. A #82A light blue filter (second from right) made the polar cap prominent. Dusky markings and light hazes jumped out when viewed with a #23A orange filter (right). Steve Fetters used a 6-inch f/8 telescope at 133x on June 14 for this sequence.



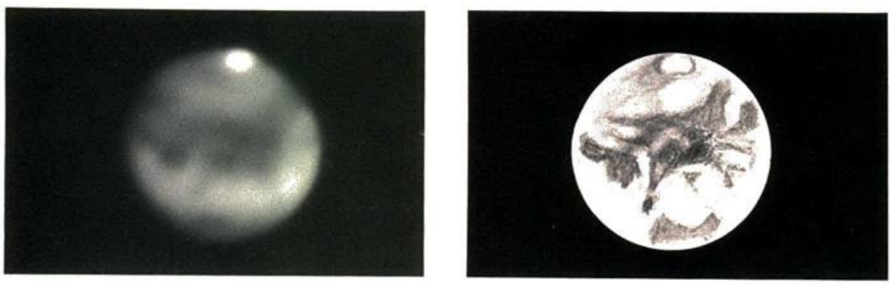
MARTIAN SPRING in the planet's Southern Hemisphere warmed and melted the icy polar cap. On August 21, Novissima Thyle, a piece of polar cap, detached from the main cap (left, visible as a wisp on the left side of the cap). By September 3 the polar cap had withered to a fraction of its former size (right). Photos by Don Parker.



THE DEMISE OF A POLAR CAP was visible in small telescopes last July and August. Dan Troiani's sketches, made with a 10-inch f/6 telescope, show the cap on July 22 (left) and August 21. In late July the cap developed a rift, and by late August Novissima Thyle, also called the Mountains of Mitchell, could be seen in telescopes as a detached white oval.



THE VALUE OF DRAWING is apparent from this photo and sketch of Mars made minutes apart on September 20 with the same telescope. Klaus Brasch's photo shows the broad, dark areas Meridiani Sinus, Sabaeus Sinus, and Aurorae Sinus. Brasch used a 14-inch SCT at f/200 for the photo. He used 313x and 434x (and a #11 yellow-green filter) for the sketch.



THE ROTATION OF MARS is visible in this photo and sketch made by Brasch an hour and a half after the above pair. Martian longitude 21° now lies on the planet's central meridian, having rotated 11° since the above pair was made. Argyre I and Solis Lacus have now appeared on the planet's right-hand limb. Brasch used a #15 yellow filter for these sketches.

surface features difficult," continued Fetters, "so I added a Wratten #8 yellow filter, but the markings still appeared faint. When I inserted a #23A orange filter, however, I couldn't believe it: the surface markings jumped out! I had a terrific view of Syrtis Major. When I changed to a #82A light blue filter, the surface detail vanished, but the South Polar Cap popped out. If you've never used filters to observe planets before, the effects are startling."

One of the favorite Martian events for observers with small telescopes was this year's melting of the South Polar Cap. Dan Troiani sketched the cap with a 10-inch f/6 reflector as spring in the southern hemisphere of Mars melted the cap. His sketch of July 22 shows a rift inside the polar cap. One month later a noticeably smaller cap and the Mountains of Mitchell, a detached piece of icy material, could be seen.

"I have observed Mars frequently since the favorable opposition in 1956," said Klaus Brasch of Jenks, Oklahoma, "and there is no doubt that this year gave us the best views ever. I have used telescopes ranging from 3 to 16 inches aperture and watched the planet under lousy and exceptional conditions. This year's combination of close approach, high elevation in the sky, and absence of major dust storms has revealed exceptional detail on the planet."

Brasch produced a comparison of the detail visible with the eye and on photographs by sketching and photographing Mars with the same telescope on September 20. Three-second exposures on Tech Pan film made with a 14-inch SCT at f/200 show large features like the South Polar Cap, Meridiani Sinus, Sabaeus Sinus, and the Hellas basin.

However, drawings made with the same telescope under the same conditions show much finer details. For example, light-colored areas near Argyre I and Hellas are clearly visible to the eye. So are small dark areas and lanes in between large features that can't be recorded on film. Brasch noted that at times the seeing became so steady that he "possibly saw the crater Schiaparelli between Meridiani and Sabaeus Sinus."

Brasch's drawings and photographs dramatically illustrate the value of both photography and telescopic sketching. Photography records a literal portrait of the planet, immune to human interpretation. The human eye transcends the resolution limit of film, recording finer details with the aid of a skillful hand. Together these techniques gave us a dramatic, close-up view of Mars in 1988.
— *David J. Eicher* ☐

THE MAGICAL BOX OF STARS

I am an avid stargazer, but I'll wager I never would have become one if I hadn't learned as a child about the magic of Grandma Maude.

My family visited Grandma Maude's hilltop farm in southeastern Ohio quite often in my youth because we tended a garden there. Even though Grandma Maude is really my cousins' grandmother, I saw her enough to think of her as mine too. She always treated us right, serving big meals from her little kitchen whenever we came to spend a Sunday hoeing weeds.

For a long time I thought she was a perfectly normal old lady. All that changed one day, however, when my younger sister and I asked our mother where the stars came from. My mom didn't know one dipper from the other, but her maternal mettle wouldn't let her leave us in limbo. She told us without hesitation that Grandma Maude hung the stars on the sky each night.

It was a startling revelation, one that demanded elaboration. Mom said Grandma Maude kept a big box of stars in a bedroom closet, and every night when it started getting dark she hung the stars up so there would be just enough light to keep it from getting pitch black but not so much we couldn't sleep. She had been granted this privilege because she lived on such a high hill, closer to the sky than the rest of us.

Well, that changed everything. Now we looked at Grandma Maude differently. We thought she was lucky, not to mention fascinating, and on subsequent visits we sometimes snuck into her bedroom and looked for the box of stars. We never found it, but then we were too short to reach the closet shelf.

It may sound corny, but I'm nevertheless grateful for my mother's whimsical fabrication, because it sparked my lifelong interest in the night sky, something I hope to inspire in my own kids.

I have introduced my seven-year-old daughter Rita to some of the classical skylore, particularly Orion and the Seven Sisters and the two bears who look like dippers. These time-honored tales are doing for Rita what my mother's off-the-cuff mythology did for me.

Last winter my daughter surprised me by pointing out for the first time and without prompting the belt of Orion and the Seven Sisters. I think she sees Orion as an ornery but lovable giant, and she shows special concern for the Sisters, puzzling like generations before her over the mystery of the one sister who got lost. "Do you think that one could be her, Daddy?" she often asks, pointing to some star hanging off by itself.

My two sons, at eight months and two years old, are still too young to get much out of our starlight conversations, but it won't be long. I hope Rita will spread the word, and I can't wait to hear what she comes up with.

Good stories are magnetic, and by telling my kids a few of the fantasies behind the facts I hope to at last pay back a debt I owe to my mother and Grandma Maude, who in her mid-eighties still lives out on her farm.

We stopped going there for several years when I was in grade school, but after I left for college my parents started camping on the farm with my cousins' families. I take my wife and kids to join them whenever we can.

A couple years ago on a sultry summer afternoon I volunteered to watch my infant son Gregory while he took a nap so the other adults could go for a swim. It was too hot for him to sleep in our tent, so Grandma Maude loaned us her bedroom and a big fan. Sitting in a chair while Gregory snoozed, I was about to doze off myself when I remembered the box of stars.

I hadn't been in this room since I was knee-high to a pop bottle, but now here I was again, older and wiser and taller, with kids of my own. And there on the closet shelf was a cardboard box.

The house was quiet except for the fan's low hum. Grandma Maude was working in her kitchen, out of earshot.

If I got up and looked, I could expand on my mom's tall tale and tell my kids I had actually peered into the box of stars.

On the other hand, if I didn't look, I would never find out for certain that there was no magic box after all, and the part of my youth that could believe in a benevolent old woman hanging stars in the twilight would be preserved.

I considered my options. And the verdict? I'm not telling. — *Robert Hecker*

THE SHOT HEARD ROUND THE UNIVERSE

This is a confession. I'm a criminal, all right, but I committed my crime in the name of astronomy. I'm not saying that makes what I did okay, you understand. I just hope that by now I'm past some statute of limitations so I can safely get it off my chest.

It wasn't on my chest until recently, however. I had forgotten all about it until the world of astronomy took up arms against light pollution and particularly high-pressure sodium security lights. Reading about that brought back the night a quarter of a century ago when in my own heinous way I was already fighting the good fight. . . .

It's 1962 and I'm a college dropout. Hiding from my parents' wrath and bad grades, I holed up in a tiny room rented from a graduate school friend and his wife. We live in a typical graduate student slum at a Texas college.

My friend Eddie has just finished building his 8-inch Newtonian. He's made it from scratch — quite a feat, even if he has been at it since he was twelve. On this particular spring night in 1962 there will be an occultation in the southern United States of Saturn by the Moon, or a graze — even the experts won't say for sure.

This occultation is a big deal to Eddie and me. But a system of new, unshielded security lights, which has just been installed to protect who-knows-what in this $50-a-month, ex-military complex where we live, is blocking our view.

A brilliant three-quarter Moon comes up over an adjacent rooftop with big, bright, beautiful, yellow Saturn right beside it, and both objects move directly behind this light that alone could illuminate Wrigley Field. I study the problem. This light is the only one near the building. Then I say in a whisper so Eddie's wife Marcia can't hear: "Eddie, get your .22. I'm going to shoot it out."

Left to himself, Eddie is a conformist, the kind of guy who needs a real leader of men to get him to do anything out of line. He puts up a hollow protest, but in the end he gets out his single-shot .22 and some shells. I crouch in a sniperlike position at an open bedroom window.

I fire. Marcia screams. The gun has a loud report, but I miss the light. Despite the noise, nobody comes running outside. So I fire again — and miss again. Now, you have to understand that I've been in the army. I was a sharpshooter, just short of expert. I accuse Eddie of having his gunsight set wrong.

Marcia shrieks that she's going to call the police, but Eddie and I aren't worried. We don't have a phone. Eddie locks her out of the bedroom and says grimly: "Let me try."

Lordy, what a tiger, I think with new respect. This guy is an honor student, a candidate for a master's degree, a teaching assistant. Unlike me, he has a lot more to lose than a fine and a few days in jail.

He hits the light with his first shot. It's a glorious moment — all that falling glass, the shower of sparks, the dying glow of the hated filaments. Then in all its unpolluted glory emerges the beautiful dark Texas sky. ! should be ecstatic, and I am — but I'm also chagrined that this egghead has beaten me to the draw.

There are no sirens or flashing lights outside, so we assume we haven't been reported. Probably nobody else around here has a phone either. We heave the monster scope outdoors and set up. We barely make it for the celestial event. The timing is so close that we practically fight over the eyepiece.

But what we see is almost worth doing hard time for. Saturn looks like a flying saucer careening across the moonscape, occasionally dipping behind mountainous craters, then again soaring clear of the Moon's horizon. When we saw it in east Texas, it is a graze; sixty miles west it is an eight-minute occultation. I've done a lot of observing since, but none that's excited me more than that night.

When it's over, we hustle the scope back in and then huddle in guilty fear. But nothing ever happens. A few days later, some guys in a truck with a ladder show up and replace the light.

I'm older now, more respectable, more fearful of authority. I probably would never do such a thing again, especially if diplomacy works on the big guys trying to sodium up our little planet at the expense of what to them is just a few specks in the sky. But to some of us that might mean never seeing the rest of creation — *William Allen* ☐

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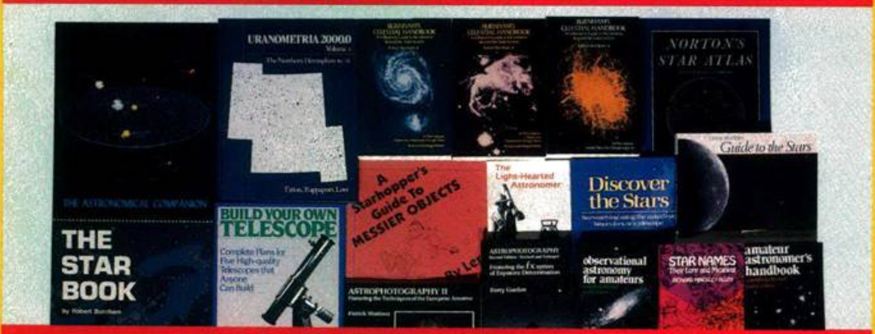

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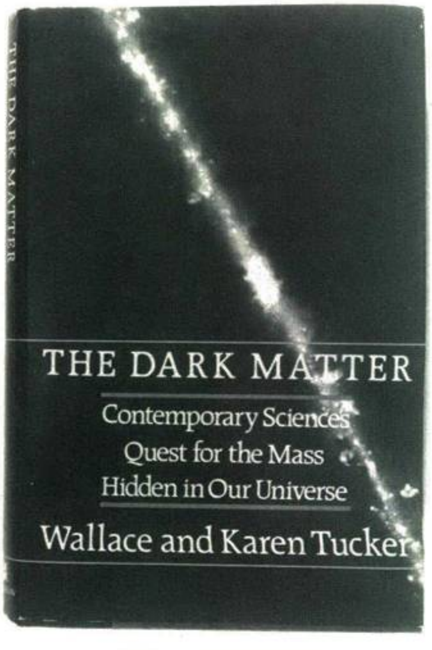
QUEST FOR THE HIDDEN UNIVERSE

The Dark Matter — Contemporary Science's Quest for the Mass Hidden in Our Universe by Wallace and Karen Tucker, (William Morrow and Company), ISBN 0-688-06112-5, hardcover, 254 pages, $16.95.

The frontiers of astronomy, like those of most other sciences, are really a tangled, confusing mess, not an orderly boundary between the known and unknown. As a result, no popular account of an astronomical frontier can be both orderly and accurate at the same time. This doesn't mean, of course, that lay people should give up as futile any effort to stay abreast of the most recent advances. It simply means that a person who wants to learn about the latest astronomical observations and theories must be willing to unlearn most of them five years from now, when those theories are either proved wrong, sink into oblivion, or otherwise fall from favor.

For a reader who understands and accepts this, *The Dark Matter* is ideal. Its theme is the existence of discrepancies between the masses of objects inferred from various gravitational phenomena, such as galaxy rotational velocities, and those obtained by adding up the masses of all relevant directly observable objects (i.e. stars that emit visible radiation, molecular clouds that radiate millimeter-wave radiation, hot gas that radiates x-rays, etc.). Such discrepancies exist in a wide variety of contexts, from objects as relatively small and mundane as our own galactic disk to the universe as a whole. These discrepancies have in some cases defied two decades of attempted explanation, and they currently occupy the full-time research staff of a considerable fraction of the professional astronomical community.



The working hypothesis is that the discrepancies are due in each case to large quantities of nonluminous but gravitationally effective matter that exists in some unknown form. Unfortunately, no one knows whether the dark-matter problems found in widely varying contexts are related aspects of a single dark-matter problem or whether some or all of them are completely unrelated. In some cases, such as the envelopes of dark matter surrounding dwarf galaxies, it is not even clear that the discrepancy is real instead of just an artifact of inadequate data or observational biases. The authors make a point of assessing the strength of the evidence for dark matter in each context they discuss. A prudent reader would do well to maintain a healthy amount of additional skepticism and a constant recollection of the provisional character of the field.

Two chapters of the book are devoted to a straightforward explanation of each situation in which dark matter must be invoked to explain observed gravitational effects. These effects include the observed oscillation of stars above and below the galactic plane as they move on (roughly) circular orbits around the disk, the rate at which the rotational velocity of stars around the Galaxy varies with the distance of the stars from the galactic center (in our own as well as in other normal galaxies), the immunity from tidal disruption exhibited by dwarf galaxies in orbit around the Milky Way, the distribution of galaxy velocities within a cluster or supercluster of galaxies, the large-scale distribution of galaxies in the universe along the edges of large "voids," and the theoretical treatments of Big Bang cosmology as constrained by the observed uniformity of the microwave radiation background.

In their last two chapters the Tuckers attempt to impose some order on the dark-matter problems by sifting out instances in which two dark-matter problems really form two aspects of the same problem or in which the observational data are too tenuous. Included in the book are chapters on related subjects, such as gravitational lenses, Mordehai Milgrom's proposed revision of the theory of gravity, and theoretical suggestions for the form that dark matter might take, all of which may or may not turn out to be relevant to the solution of the current mystery.

In their selection of research projects to describe, the authors chose to err on the side of credulity rather than skepticism. For example, devoting an entire chapter to Milgrom's modified gravity is very generous for a theory lacking any observational proof and lying at (or beyond) the fringe of acceptability for most of the astronomical community. The authors also consider the existence of significant voids in the large-scale distribution of galaxies to be a well-established fact, so well established that the failure of current galaxy formation theories to account for voids (without invoking dark matter) counts as a true dark-matter problem. This "foamy" form of the large-scale galaxy distribution — large bubbles or voids bounded by narrow "walls" in which the galaxy concentration is high — is still highly controversial, however. It may turn out that finding a "void" as large as the largest one currently known (located in the constellation Bootes) in a completely random spatial distribution of galaxies is not all that unlikely. If the skeptics are correct, then there are no dark-matter problems associated with voids at all.

As long as readers remember that they are not reading a textbook but rather an account of ongoing and often controversial research, they won't be misled. The writing style is direct, and the level of discussion is simple enough for readers with no aptitude for mathematics or science to follow.

Occasional anecdotes give the book a bit of human interest. Together with the scientific exposition, this all adds up to provide the reader an accurate picture — complete with the oddball hypotheses and the eccentric characters — of the clamor and ferment currently prevailing in an important branch of astronomical research — *Erich Grossman, University of Texas*

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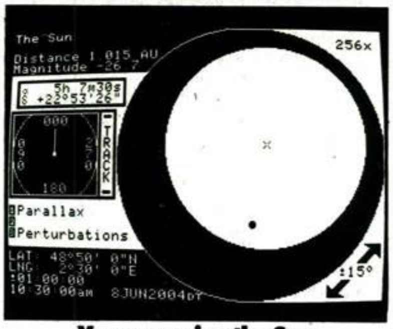

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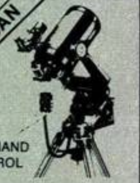

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ISBN 0-521-33086-6, 128 pages, $60; volume II: ISBN 0-521-33087-4, 282 pages, $75; set: ISBN 0-521-12579-X, $125.

In the mid-1960s Halton Arp published an atlas of over three hundred unusual galaxies in the Northern Hemisphere that he identified as peculiar on the plates of the *Palomar Sky Survey*. The work was called the *Atlas of Peculiar Galaxies* and in no time it became a classic in astronomy literature. (Unfortunately this atlas is no longer available except on the rare book market, and even there copies are pricey).

Late last year Cambridge University Press published Arp's new atlas of peculiar galaxies of the Southern Hemisphere, and this work, too, promises to become a classic. This time Arp brings his eye for unusual and downright bizarre galactic shapes to bear on the deep plates (limiting magnitude of 22) taken by the United Kingdom's 1.2-meter Schmidt telescope at the Anglo-Australian Observatory in Australia. Arp's collaborator is Caltech astronomer Barry Madore, who has done much work on the distance scale of the universe. The formidable task of searching for unusual galaxies on 537 plates took seven years; collating the tabular information took another three years.

The stated purpose of the atlas is to provide insights into the physical processes at work in the realm of galaxies. Astronomy still has a long way to go toward understanding the behavior of isolated galaxies, not to mention the fundamental processes at work in galactic collisions and interactions. It is in the aberrations caused by nuclear activity, galactic winds, and tidal encounters that many of the dynamic forces that shape all galaxies become manifest.

Clearly the atlas is a valuable resource for professional astronomers. But it also may interest amateur astronomers who enjoy nature's peculiarities. Flipping through the photographic catalog, one marvels at the variety of contortions and forms: galaxies that look like seagulls, nautiluses, and scythes; galaxies with shredded arms, hollowed-out centers, loops, and broad dust bands. The images are startling and beautiful.

The catalog covers the sky from the south celestial pole to −22°. Volume I contains information such as the galaxy's right ascension and declination, the galactic and supergalactic longitude and latitude, and a brief description of each object as well as cross-identifications to other catalogs. Volume II contains 1,017 negative photographs (black stars, white background). The photographic catalog is divided into twenty-six general-structure categories, each of which is further divided into subcategories.

For example, category one is "Galaxies with Interacting Companions." These are spiral galaxies that have a smaller companion that is either perturbing the larger galaxy or is itself distorted. Subcategories include "Strong Interaction with Spiral Arms," "Strong Interaction with Main Body," "Wider Interactions," and "Less Strong Interactions."

Other main categories cover the complete range of galaxy distortions: "Ring Galaxies," "Galaxies with Peculiar Spiral Arms," "M51-Types," and "Chains," to name a few.

If you think that galaxies are all symmetry and grace, take a look at some of the examples in Arp and Madore's book. As was said in the introduction, galaxies do not exist in total isolation. They interact with other galaxies and this often modifies, sometimes dramatically, their shapes. — *Jeff Kanipe*

PROCEEDINGS

Progress and Opportunities in Southern Hemisphere Optical Astronomy, edited by V. M. Blanco and M. M. Phillips, (Astronomical Society of the Pacific Conference Series, 1988), ISBN 0-937707-18-X, hardcover, 427 pages, $32.

RADIO ASTRONOMY

Millimetre and Submillimetre Astronomy, edited by R. D. Wolstencroft and W. B. Burton, (D. Reidel, 1988), ISBN 90-277-2763-5, hardcover, 393 pages, $99.

STARS

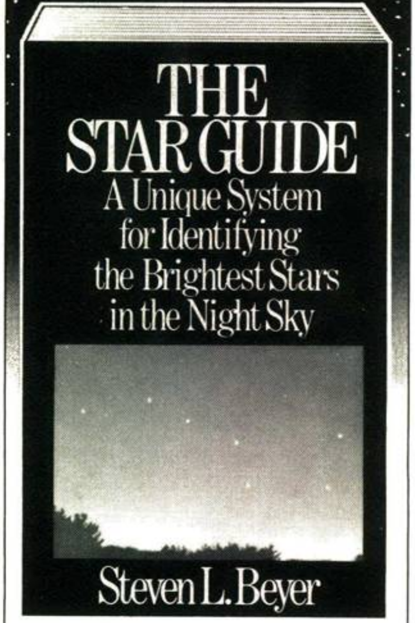
Atlas of the Ultraviolet Sky by Richard C. Henry *et al.*, (Johns Hopkins University Press, 1988), ISBN 0-8018-3738-3, hardcover, 457 pages, no price given.

Atmospheric Diagnostics of Stellar Evolution: Chemical Peculiarity, Mass Loss, and Explosion, edited by K. Nomoto, (Springer-Verlag, 1988), ISBN 3-540-19478-9, hardcover, 468 pages, $45.70.

O Stars and Wolf-Rayet Stars, edited by Peter S. Conti and Anne B. Underhill, (NASA SP-497, 1988), GPO stock number 033-000-010-21-4, paperback, 500 pages, $24.

SUN

Astrophysics of the Sun by Harold Zirin, (Cambridge University Press, 1988), ISBN 0-521-302684, hardcover, 433 pages, $49.50. ☐



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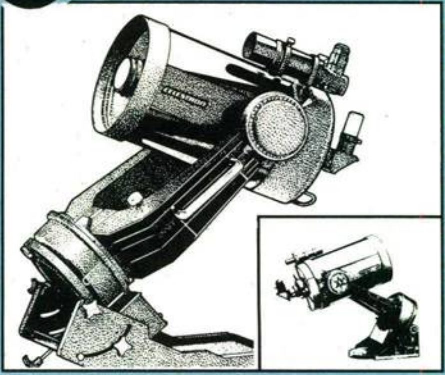

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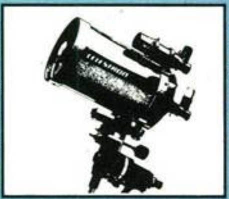

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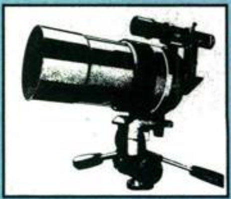

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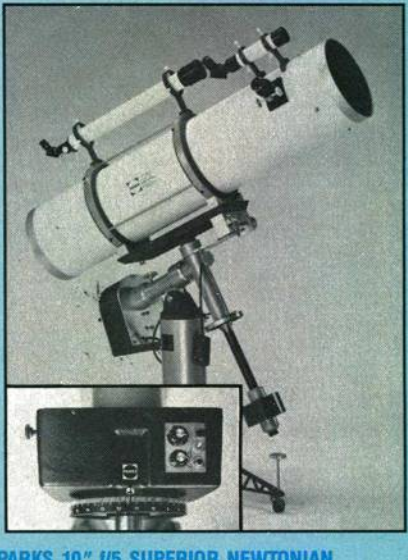

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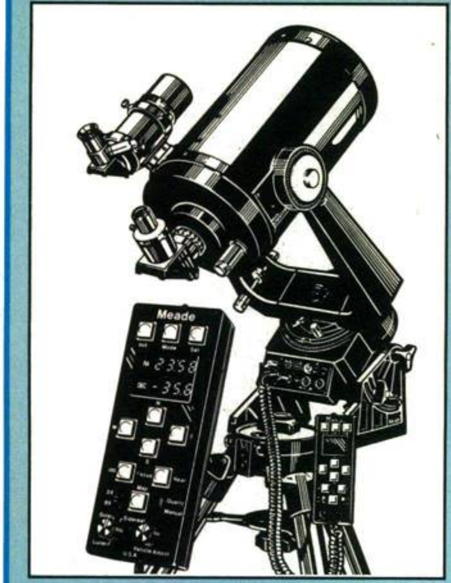

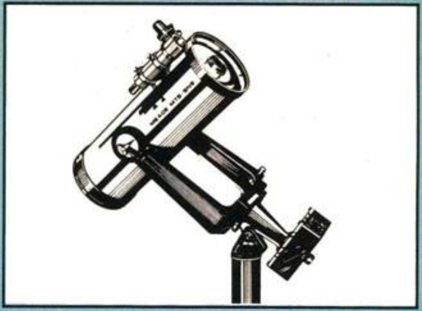

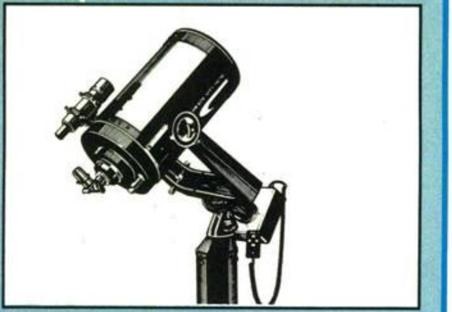

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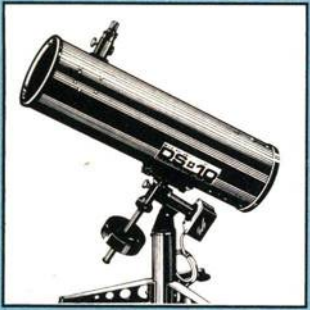

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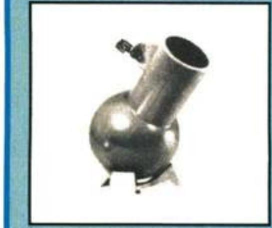

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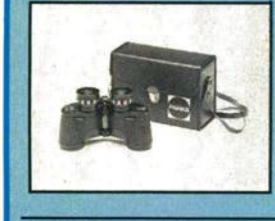

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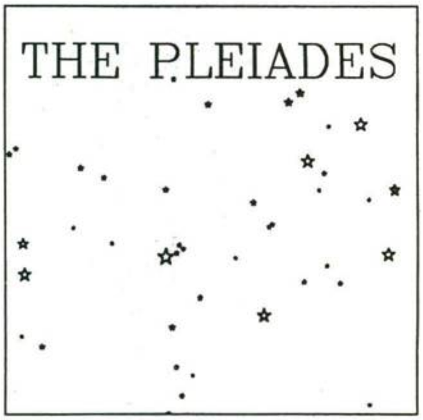
SOFTWARE

Genesis Project, (Lewis-Michaels Engineering, 48 Delemere Boulevard, Fairport, NY 14450), no price given.

Designed for the PC-XT, AT, or 100 percent compatibles (with DOS 3.0 or higher), the *Genesis Project* can create star maps (from −30° to +90°) using any of nine map projections. The maps use a database (supplied) with 190,000 stars down to 11th magnitude. In addition, the software can give you a horizon view for any given date, time, and location on Earth. The program also contains software for creating contoured plots of digitized photos or tabular data and can generate a three-dimensional (solid-surface) view of the data. Other subroutines let you design telescopes and develop graphics for display.



THE PLEIADES as seen in the *Genesis Project*'s detailed mapping mode.

VIDEOTAPES

Seven Days in Space, (Halcyon Films and Video, 110 Beach Road, Kings Point, NY 11024), 88 minutes, $29.95.

If network coverage of shuttle flights leaves you feeling as if most of the things you want to see are chopped out, *Seven Days in Space* goes a long way toward filling that gap.

The video profiles the week-long November 1984 flight of *Discovery* with Rick Hauck (commander), Anna Fisher, Joe Allen, Dale Gardner, and David Walker. *Discovery*'s mission (logged as 51-A) was to retrieve two communications satellites stuck in bad orbits and deliver two other satellites to space.

The video is excellent. You get a good look at the preparations, followed by dramatic shots of the launch itself, as seen from the ground and from a chase plane in the air.

Once the shuttle is in orbit, you are taken on a tour of the craft (together with the requisite demonstrations of weightless silliness), and then the crew gets to work launching the two new communications satellites carried up from the ground, *Telsat H* and *Syncom 4-1*.

The process of launching these satellites is visually intriguing. Each is carried in the payload bay in a white cabinet with a clam-shell lid. The lid opens to reveal the satellite, which begins to spin (for stability), and then a spring kicks the whirling satellite straight up and out of the bay. The effect looks like a slow-motion parody of *Discovery*'s own launch.

With both satellites gone, the chase and retrieval of the two ailing satellites, *Palapa B2* and *Westar VI*, follows.

The capture of *Palapa* is the longest episode in the video. You first see the satellite as a brilliant point of light in the distance, like Venus. It grows larger as *Discovery* closes on it; slowly the satellite takes shape as a large, chunky cylinder spinning about ten times a minute. You watch fascinated as Dale Gardner coasts untethered out to the satellite and snags it with difficulty. Eventually, with the help of Joe Allen (and Anna Fisher, running the remote control arm from inside the cabin), the astronauts manage to wrestle all 1,250 pounds of *Palapa* into the payload bay and latch it down.

This sequence powerfully brings home to you again, with sights we haven't seen for the past three years, just what it's like to live and work in an environment where you must think two or three times before you make a move — and none of your ground-bound reflexes can be trusted.

The salvage of the *Westar* is dealt with more quickly because it went smoother than the *Palapa* recovery. The de-orbit burn follows and landing at Kennedy Space Center finishes the story — in fact, the trailing credits roll over a long telephoto shot looking straight down the runway as *Discovery* floats into the frame and touches down.

Edited with skill and intelligence, this video is a masterpiece of selective compression. It is leisurely and unhurried but never drags. The soundtrack enhances the action but at no time upstages it. Because the video is narrated solely by the astronauts of the mission, it has an immediacy and a realism that no professional narrator could give. And although it has its corny moments, the video as a whole is *dignified*. These five people are doing a serious and dangerous job and the video respects that, neither making it pompous nor trivializing it.

You come away thinking that this is a movie the crew members shot for your benefit so you'd understand what they did while they were away in space.
— *Robert Burnham* ☐

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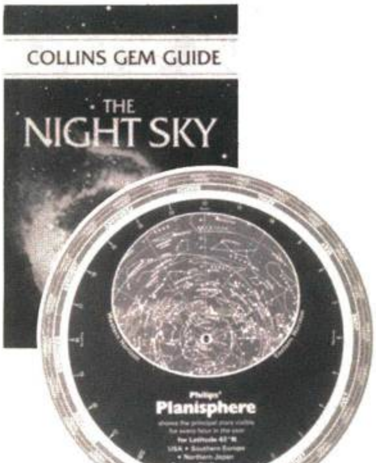

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Meetings and Events

January 8-12
173rd Meeting of the American Astronomical Society, Boston, Massachusetts. Professional meeting hosted by the Massachusetts Institute of Technology. Contact: American Astronomical Society, 2000 Florida Avenue, N.W., Suite 300, Washington, DC 20009.

January 14
Astronomy Day, Columbus, Georgia. Sponsored by Patterson Planetarium. Contact: Carole Rutland, Director, Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, GA 31907. Phone: (404) 568-1730.

February 2-5
5th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

March 9-12
Third New Zealand Photo-Electric Conference, Blenheim, New Zealand. Contact: Stan Walker, Auckland Observatory, P.O. Box 37 735, Auckland, New Zealand. Phone: 64 (9) 548-736.

March 18
New England Astro-Fest #2, Farmington, Connecticut. Commercial astronomy equipment exhibition, sponsored by New England Astro-Optics, Inc. Contact: New England Astro-Optics, Inc., Attention: Astro-Fest #2, P.O. Box 834, Simsbury, CT 06070.

May 13
16th Annual Astronomy Day. Contact: Gary E. Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson Avenue S.E., Grand Rapids, MI 49503. Phone: (616) 456-3985.

May 19-21
Royal Astronomical Society of New Zealand Conference, Invercargill, New Zealand. Sponsored by the Southland Astronomical Society, Inc. Contact: Darryl Jones, Southland Museum and Art Gallery, P.O. Box 1012, Invercargill, New Zealand.

May 29-June 4
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: T.S.P. Registrar, Bobby Braley, Department "A", P.O. Box 386, Wylie, TX 75098.

June 21-25
Centennial Meeting of the Astronomical Society of the Pacific, University of California at Berkeley. Contact: Berkeley Meeting Information, A.S.P., 390 Ashton Avenue, San Francisco, CA 94112.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. ☐

READER EXCHANGE

WANTED – French girl, twenty-three, seeks correspondence with persons worldwide interested in astronomy and science fiction. Contact Helene Hugot, 78 Bd. F. Duparc, 13004 Marseille, France.

WANTED – Correspondence with amateurs interested in early (pre-1920s) books on astronomy and life on other planets. Contact Thomas Sandberg, Ostra Storgatan 25, 694 00 Hallsberg, Sweden.

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WANTED – Observations of the Perseid meteor shower from any year for observational data collection and analysis. Contact Gregg Pasterick, 375 Forest Street, Columbus, OH 43206. Phone (614) 444-7998.

WANTED – Celestron C5. Contact M. Kitt, 99 Bronxville Road, Bronxville, NY 10708. Phone (914) 961-7860.

WANTED – Fifteen-year-old American male seeks correspondence with other teens (male or female) interested in astronomy living in England and Europe. Contact Carl Piazza, Jr., 1353 East Airdrie Street, Philadelphia, PA 19124-5540.

WANTED – Tape recording of "Dial-a-Shuttle" coverage of the last flight of *Challenger*, Mission 51L. Will pay. Contact Simon Perl, 27 Doris Road, 7700 Claremont, South Africa.

WANTED – Criterion 6" Dynascope. Whole, partial, or parts. Also interested in accessory items. Send price list and phone number for prompt reply. Contact Michael Lawson, P.O. Box 1542, Flagstaff, AZ 86002.

WANTED – Amateur astronomer would like to correspond with other amateur astronomers worldwide. Also interested in joining an international astronomy club or association. Contact A. Arief, 14-K, Lorong Puyoh, 05000 A. Setar, Kedah, Malaysia.

WANTED – Large-aperture binoculars (at least 20x120). Contact Paul Carmody, 9110 2nd Avenue, Silver Spring, MD 20910. Phone (301) 588-1351.

FOR SALE – Edmund 10" tube assembly, diagonal holder, 2" focusing tube. Missing optics. $90. Complete 14-1/4" f/4.5 tube assembly. $325. Telescope mounts complete and incomplete — German, yoke, and fork with 1-3/4" shafting. Priced to sell. Shipping not included in prices. Photos and details available. Contact Paul Rini, 19 Knollwood Drive, Cherry Hill, NJ 08002. Phone (609) 667-0783.

FOR SALE – Celestron 5.5" Schmidt-Newtonian with 8x5 finder, 25mm eyepiece, Celestron equatorial mount, and tripod. $450. Celestron C-90 with star diagonal, 18mm eyepiece, dust cover, and carrying case. $200. Celestron RFA. One year old. $75. Phone George Sroczynski at (201) 257-2383 (evenings).

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FOR SALE – Celestron SPC8 with Starbright coatings, 6x30 finder, SA motor drive on Super Polaris mount, 26mm Plossl, full-aperture solar filter, and trunk. $950 prepaid. Contact Terry Smith, 9 S.E. 5th, Linton, IN 47441. Phone (812) 847-2532.

FOR SALE – Meade 2080 f/10 telescope with case and tripod with accessory tray. Includes illuminated 50mm polar finder, camera piggyback mount, rear cell camera adaptor, two eyepieces, declination motor, full-aperture solar filter, telecompressor, tele-extender, and off-axis guider. Perfect condition. $1,090. Contact Jay GaBany, 918 Pheasant Run Drive, Gaithersburg, MD 20878. Phone (301) 977-8270 (evenings).

FOR SALE – Celestron Super C8 Plus with tripod, wedge, 26mm Plossl, 7mm Ortho, 8x50 finder scope with illuminated eyepiece, star diagonal, and much more. Mint condition. $995 plus shipping. Contact Debi Kerins, 17028 Smith Prairie Road, Yelm, WA 98597. Phone (206) 894-2714.

FOR SALE – ASTRONOMY. Various issues from 1981-1989. Good condition. $45. Phone Mike at (419) 536-7579.

FOR SALE – ASTRONOMY. May 1974-present. Missing three issues. All in good condition. $150. Contact C. M. Boso, Jr., Route 1, Box 126, Washington, WV 26181. Phone (304) 863-6710.

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FOR SALE – Meade 10" 2120 LX5. All standard accessories including wedge, tripod, 20mm eyepiece, carrying case, declination motor, and more. Less than one year old. $1,600. Contact 1454 Lazy Trail Drive, Chico, CA 95926. Phone (916) 893-2981.

FOR TRADE – Atlas 210x Special Edition with console for Celestron 20x80 or 30x80 deluxe binoculars. Contact Scott McCann, 111 Old Mill Bottom Road, Annapolis, MD 21401. Phone (301) 757-1991.

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FOR SALE – ASTRONOMY back issues. March 1980-present. $100 plus shipping. Phone Tony Repice at (609) 268-8770.

FOR SALE – *Telescope Making*. #1, #2, #8, #13, #14. $5 each. *Planetary Astronomy*. #1. $4. *Science Digest*. 1970s. $1 each. *Popular Science*. 1970-1971. $1 each. *UFO Review*. #3, #5, #14-#16. $2 each. *Handbook of Natural Phenomenon* by William Corliss. $7.50. *Unexplained, Sourcebook of Strange Phenomenon* by William Corliss. $2. *Earth in Upheaval* and *Worlds in Collision* by Immanuel Velikovsky. $2.50 each. *UFO Prophecy* by Arthur Shuttlewood. $5. Phone (304) 369-2216.

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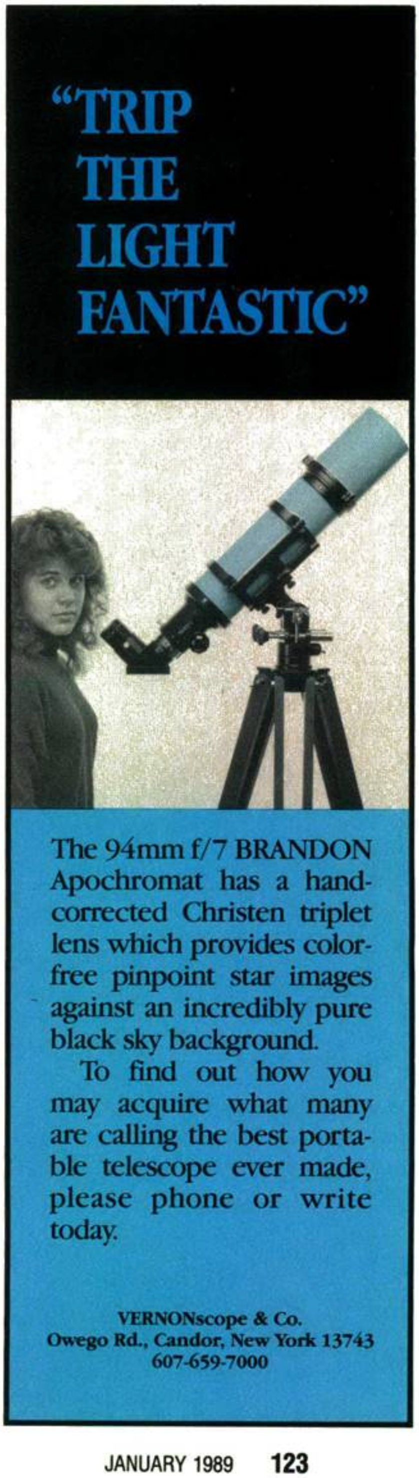
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Readings and Resources

Venus and Jupiter (page 24)

The Space-Age Solar System by Joseph F. Baugher, (John Wiley & Sons, 1988). A review of what spacecraft have revealed about the solar system for the reader interested in a detailed scientific discussion of planets, atmospheres, comets, and other objects.

The 21st Century (page 44)

Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015, (National Academy Press, 2101 Constitution Avenue, N.W., Washington, DC 20418, 1988). The seven-volume set (#03899-5) can be ordered for $67. The individual volumes are titled *Overview*, *Astronomy and Astrophysics*, *Fundamental Physics and Chemistry*, *Life Sciences*, *Mission to Planet Earth*, *Planetary and Lunar Exploration*, and *Solar and Space Physics*. They may be ordered separately for $12 apiece.

***Discovery's* 'Cargo of Dreams'** (page 54)

Before Liftoff: The Making of a Shuttle Crew by Henry S. F. Cooper, Jr., (Johns Hopkins University Press, 1987). The reader follows the crew of Mission 41-G through a year of intense training leading up to launch on October 5, 1984.

Space Shuttle: A Quantum Leap by Georges Torres, (Presidio Press, 1987). A general overview of the shuttle, its future, and the direction of the U.S. space program.

1989 Sky Guide (page 78)

Association of Lunar and Planetary Observers, c/o Henry Jamieson, P.O. Box 143, Heber Springs, AK 72543.

International Occultation Timing Association, 6 N 106 White Oak Lane, St. Charles, IL 60174.

City Astrophotography (page 90)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). A basic, well-written how-to book on astrophotography.

Winter Star Clusters (page 98)

Atlas of Deep-Sky Splendors, fourth edition, by Hans Vehrenberg, (Sky Publishing Corp. and Treugesell-Verlag, 1983). An excellent photographic atlas that includes many bright star clusters.

The Universe from Your Backyard by David J. Eicher, (AstroMedia and Cambridge University Press, 1988). A constellation-by-constellation tour of star clusters, galaxies, and nebulae.

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Penetrating Triton's Mysteries We know surprisingly little about Neptune's moon Triton, but that will change next August.

Barnard's Dark Dilemma E. E. Barnard discovered dark nebulae, but he never came to grips with the significance of his discovery.

Eclipse Prospects for the 1990s With this report on eclipse weather you can start planning your eclipse expeditions for 1990 and 1991.

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ANNOUNCEMENT – The SSED (Supporters of Space Exploration and Development) is looking for members. The SSED's purpose is to help NASA with its money problems. Quarterly newsletter with wonderful items for sale in the classified advertisement section. All profits are donated to NASA. Explore the universe with us and help NASA along the way. Please write for details (SASE appreciated). Contact Jimmy Gilliam, SSED, Route 6, Box 170, Searcy, AR 72143.

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ANNOUNCEMENT – Call for papers for the 1989 Regional Convention to be held in Tulsa, Oklahoma. Send abstract, request for time slot, and equipment required. Please submit papers by March 1989. Contact Astronomy Club of Tulsa, c/o Don Cole, P.O. Box 470611, Tulsa, OK 74147-0611.

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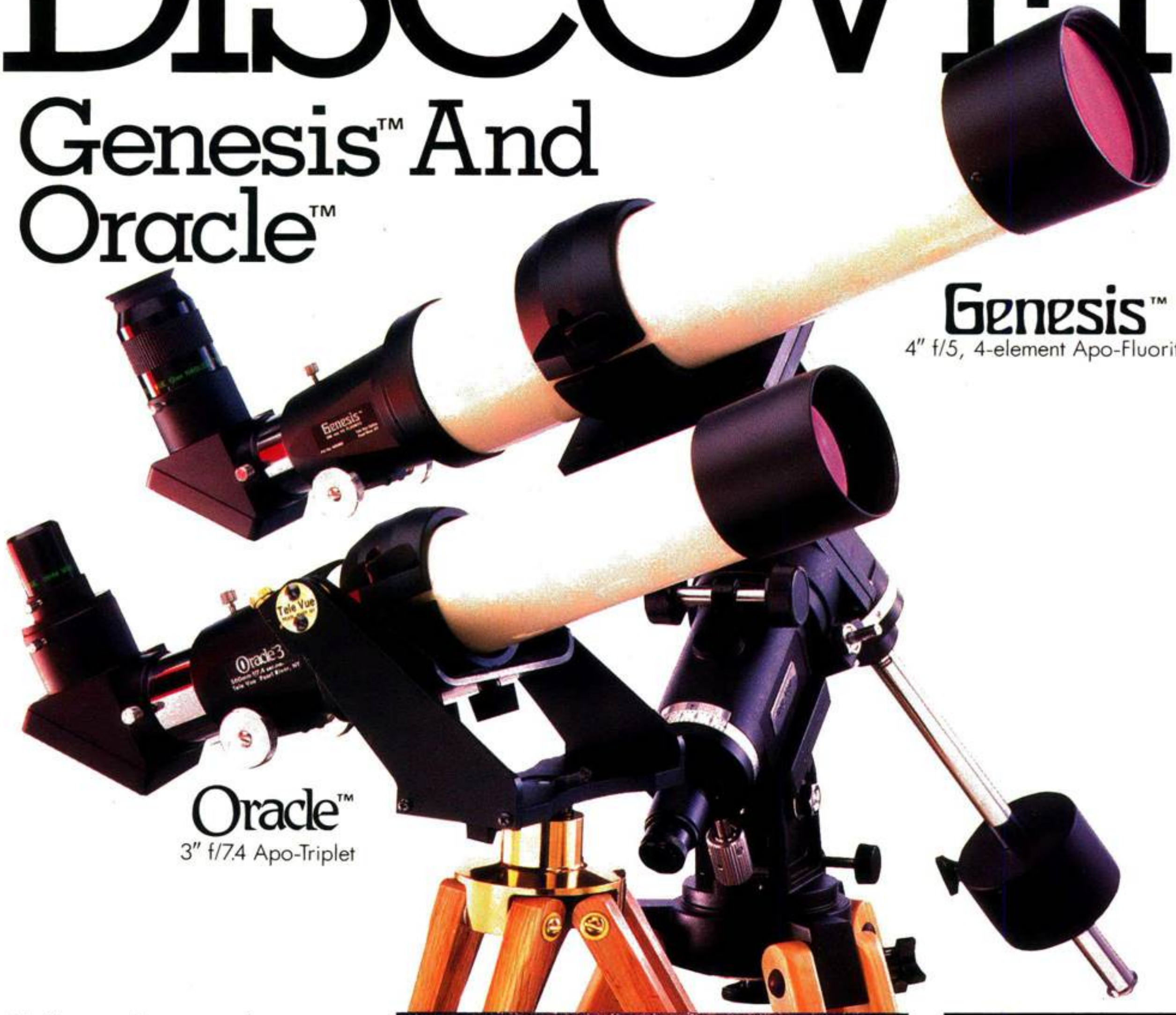

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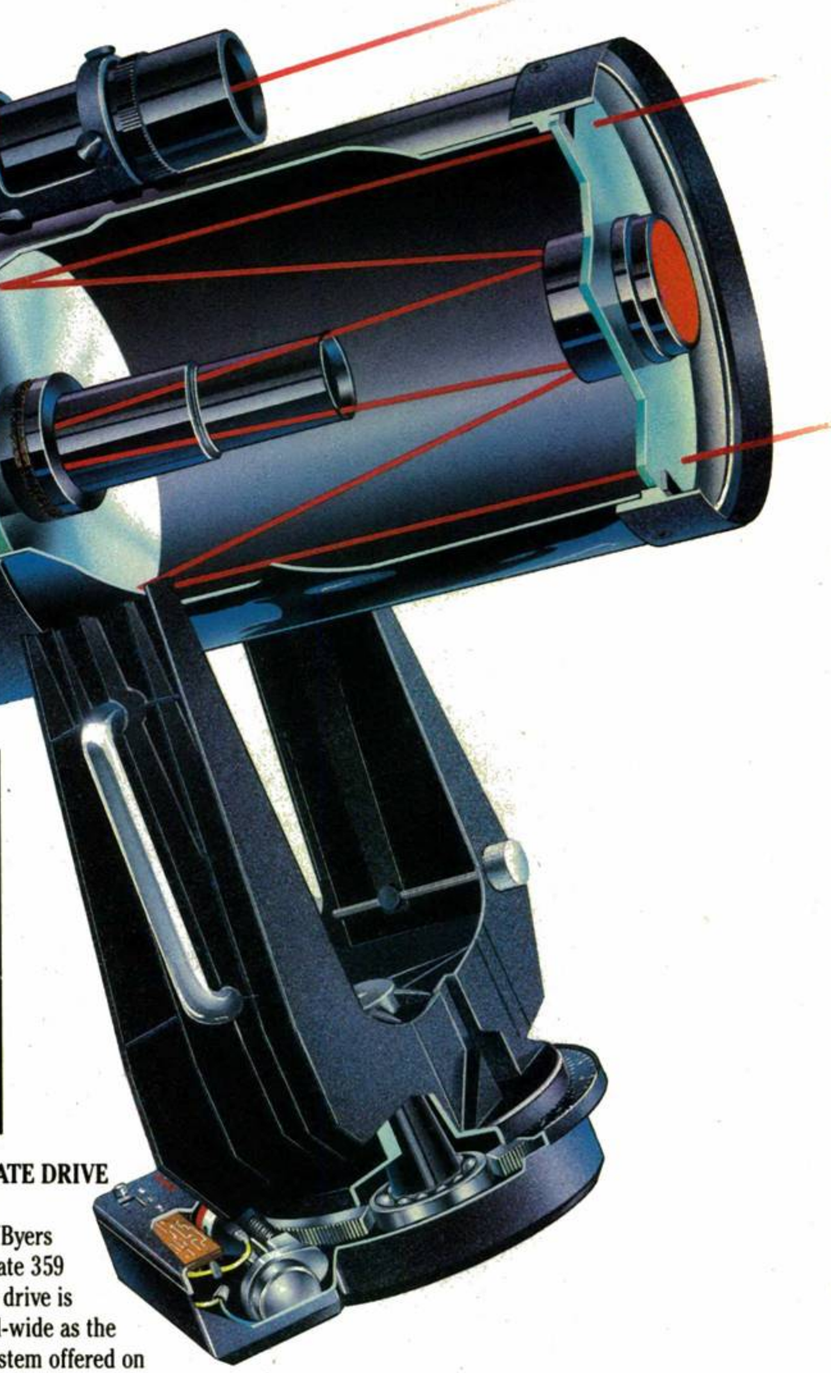

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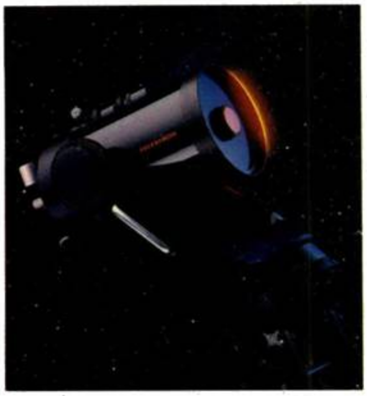

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